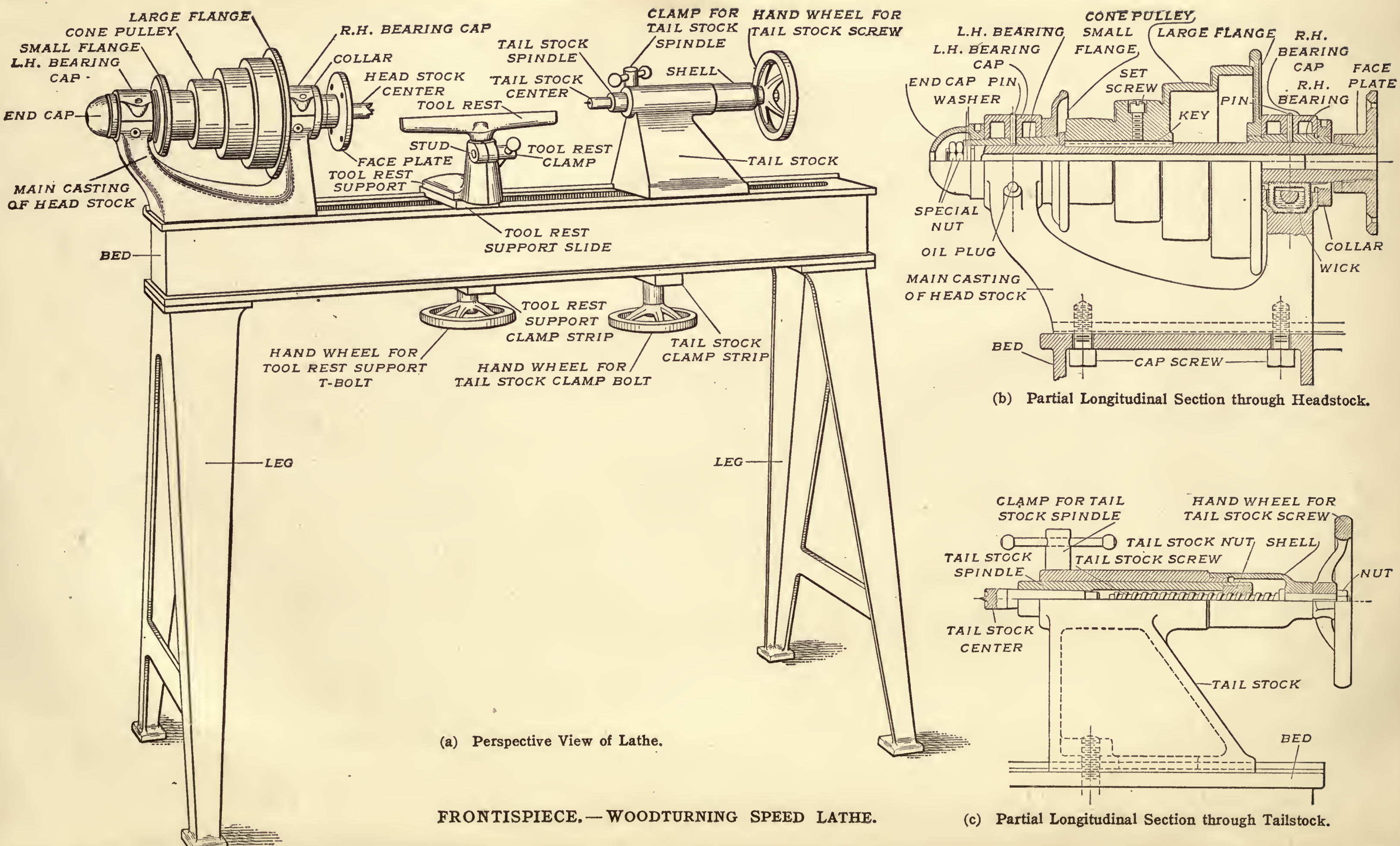



(a) Perspective View of Lathe.

(b) Partial Longitudinal Section through Headstock.

(c) Partial Longitudinal Section through Tailstock.

FRONTISPIECE.—WOODTURNING SPEED LATHE.

# Elements of Drawing

BY

GEORGE F. BLESSING, M.E., Ph.D.

Professor of Mechanical Engineering and in charge of Engineering, Swarthmore College
Formerly Assistant Professor of Machine Design, Cornell University

AND

LEWIS A. DARLING, E. in M.E.

Engineering Department Remy Electric Co., Formerly Assistant Professor of
Machine Design, Cornell University

*FIRST EDITION*

SECOND THOUSAND

NEW YORK
JOHN WILEY & SONS
London: CHAPMAN & HALL, Limited
1913

T3
B6

BY THE SAME AUTHORS

ELEMENTS OF DESCRIPTIVE GEOMETRY

8vo, xvii + 219 pages, 168 figures. Cloth, $1.50 net.

CONTENTS.—Preface. Introduction. Definitions, Notation and First Principles, Problems on the Point. Point and Line Problems. Line and Plane Problems. Solids. Tangent Planes and Double-Curved Surfaces of Revolution. Sections. Intersections and Developments.



Stanhope Press
F. H. GILSON COMPANY
BOSTON, U.S.A.

# PREFACE

It is the purpose of this book to present a course of instruction in Elementary Drawing for beginners who intend to pursue a course in engineering or who desire to prepare themselves to do commercial drafting. The work herein outlined, as well as that contained in the companion volume, "Elements of Descriptive Geometry" by the same authors, is based on the drawing-room courses required of all first-year students in Mechanical and Electrical Engineering in Sibley College, Cornell University, as a preparation for the more advanced work of design in the second and third years of the course, which is also required of all students in the college.

The task of writing the book and its companion volume was undertaken by the authors, at the writer's request, while they were members of the staff of instruction of the Department of Machine Design and Construction of Sibley College. The object in view was twofold, namely, to obtain a book exactly suited to the needs of the Department, which we had heretofore been unable to do; and also to put into permanent shape the methods and principles used in this work, thus forming one of a correlated series of texts which eventually, it is expected, will fully cover the entire work of the department. The authors brought to the task a full knowledge of the more advanced work of the Department, having had experience in teaching these advanced subjects in design which, with their experience elsewhere both in practical and teaching positions, was of great aid in improving and refining this more elementary work.

There is nothing experimental in the principles or methods outlined in the book, as most of them have been in constant use in Sibley College for years and have been productive of most excellent results, not only in teaching the art of elementary drawing but as a preparation for the more advanced work in design.

Particular attention is given in the drawing-room work in Sibley College to the art of lettering and the methods presented in the chapter on lettering have been remarkably successful. Only two alphabets have been presented, it being considered best to confine the student's efforts to a thorough study and practice of those two which are of almost universal use rather than to make a superficial study of more elaborate alphabets which find very limited, or no use. The system of spacing was very largely developed by Prof. John T. Williams, who has taught it for a number of years with marked success. The authors have refined the system and also developed and presented a spacing chart, as it is believed that some instructors may prefer its use to that of rules.

In regard to the material on "drawing-room system," no claim is made by the authors that it is the best in the sense that there is a best system, but it is their belief, which is based on considerable experience, that if this system is well understood by the student he will have no trouble in understanding any other he may be called upon to work with.

Chapter V has been presented because of the growing popularity of isometric drawing in practically all branches of technical work.

It will be noted that though the book is based on the practice of Sibley College it is written in a flexible manner so as to be adaptable to almost any logical sequence of presentation, the general text matter applying equally to the drawing-board course presented or to a beginners' course arranged by instructors in the subject. The following suggestions by the authors as to the use of this book will make this clearer.

The text matter is intended to give in a practical and concise form such information as the beginner should have in order to intelligently pursue the drawing-board work.

*It is not supposed that lessons be assigned for recitation after the manner usually followed in teaching textbooks*, that is, by beginning with Chapter I and assigning consecutive paragraphs to the end. The paragraphs should be assigned *at the time the information can be applied directly to the drawing being executed.* To facilitate this method each drawing plate

has certain paragraphs assigned and at the completion of the plate there should be an examination, oral or written, covering these paragraphs. The proper method of covering the text previous to examinations will depend upon the methods of the institution using the book. It is most desirable to have regular recitation periods, and the authors believe one hour per week upon recitation should cover the work satisfactorily. Where this is impracticable the instructor should question the student *as he proceeds with his work in the drawing-room.* Especial attention should be directed to points where the student's work shows a lack of knowledge and he should be required to refer at this time to the parts of the text covering the points in question.

Where the book is used in this manner, that is, simply as a book of reference, a preliminary examination should be held after the completion of *each* plate. The instructor should constantly keep in mind the object of this book, which is to teach the student:

1st, how to select, care for, and use drawing instruments.
2nd, how to make and read technical drawings.
3rd, how to think over the drawing board.
4th, to lead him to consider the relation drawing bears to design, shop processes, and shop organization.

The third and fourth items are not usually given the attention their importance demands, and it is not unusual to see a college graduate make a beautiful drawing which is full of errors, due to the fact that all thought has been given to the drawing paper and none to the object it represents or to the shop methods necessary to produce this object. To aid in overcoming this difficulty the authors have avoided the use of models of the geometric or kindergarten type or of machine parts selected at random.

The models selected are parts of a wood-turning speed lathe, and are selected because the students will most likely be more familiar with this machine than any other. Also in most places where this course is taught the student will be working on his wood-turning exercises in the shop, on this machine, at about

the same time he is doing his drawing. For this reason he is most apt to study the principles of design involved, the relation of parts, etc., and thus do his work in a much more intelligent manner than if he held no further interest in the model than that of making a dimensional picture of it.

DEXTER S. KIMBALL,
*Professor of Machine Design and Construction,*
Cornell University.

June 8, 1912.

## AUTHORS' NOTE

The authors are deeply indebted to Prof. J. T. Williams of Sibley College, Cornell University, without whose assistance and coöperation this book in its present form would not have been possible.

Grateful acknowledgment is also made of assistance by Prof. D. S. Kimball in developing the book and outlining its scope, and to Prof. G. W. Lewis, Messrs. A. Kessler and L. J. Bradford for assistance in preparing material and reading proof.

# CONTENTS.

## CHAPTER II.

### LETTERS, NUMERALS, AND LETTERING.



### SET OF FREE-HAND LETTERING EXERCISES

## SET OF MECHANICAL DRAWING EXERCISES



## CHAPTER IV.

### FREE-HAND WORKING SKETCHES.

## SET OF FREE-HAND DRAWING EXERCISES

## CHAPTER V.

### Isometric Drawing and Sketching.

## SET OF FREE-HAND ISOMETRIC EXERCISES

# ELEMENTS OF DRAWING

## CHAPTER I

## SELECTION, CARE AND USE OF DRAWING INSTRUMENTS AND MATERIALS

1. **Introductory.** The accuracy and finish of mechanical and geometrical drawings, as well as the speed with which the draftsman works, depend to a very large extent upon the *quality* of instruments used. To secure the best results the most experienced draftsman requires instruments of a *first-class* quality, and as the beginner needs all the assistance possible, he should not handicap himself by using instruments of an inferior grade. Since, in this work, a knowledge is required of what goes to make up instruments of a first-class quality, such knowledge should be gained before purchases are made, in order that the fullest benefits may be obtained. Thus unsatisfactory work, in so far as it results from the use of inferior instruments and supplies, can be avoided.

**The quality of an instrument** must not be judged entirely by its cost, but by its design, accuracy of workmanship, and the materials from which it is made. Some of the more costly instruments are designed for extreme accuracy of adjustment, and are so delicate in mechanical construction that ordinary usage soon renders them less accurate than the cheaper but more substantial makes. Hence, in selecting instruments it is best to avoid those of extremely delicate construction, for as a rule instruments of simple design prove most satisfactory, especially for beginners.

The best of instruments, however, will soon deteriorate and become unsatisfactory unless properly cared for, and the beginner is especially urged to cultivate the habit of seeing that his instruments are *always* kept in the best shape possible.

In the following paragraphs instruments are briefly described and the essential points which determine their superiority are noted. Before purchasing instruments read the first portion of each item referred to in the following paragraph and, if possible, consult with some experienced person as to the names of reliable makers of instruments and supplies.

**2. List of Instruments and Supplies Necessary for the Complete Course:**

**Drawing Paper (M)*.** 10 sheets of drawing paper accurately cut to 12″ × 18″ and punched. (See page 4, § 3.)

**Ruled Paper (L), (S).** (a) 36 sheets 8″ × 10½″ standard punched (for #10 Manila cover), extra heavy weight cross-section paper, ruled on one side only with lines ⅛″ apart and every eighth line heavy. (See page 5, § 4.) (b) (S) 6 sheets 8″ × 10½″ standard punched extra heavy weight isometric paper ruled on one side only. (See page 5, § 4.)

**Tracing Cloth (M).** 4 yards 18½″-wide tracing cloth of best quality. (See page 6, § 6.)

**Blue-print Paper (M).** ½ yard 36″ wide slow acting blue-print paper of best quality. Not to be purchased until required. (See page 6, § 7.)

**Drawing Boards (M).** (a) 1 pine drawing board 19″ × 26″. (See page 7, § 8.) (b) **(L), (S).** 1 well seasoned pine board 10″ × 12″ × 5/16″ thick.

**Thumb Tacks (A).** 1 dozen thumb tacks with small round heads about 5/16″ diameter. (See page 8, § 9.)

**T-Square (M).** 1 T-square with solid head and polished surfaces. Blade 26″ long and preferably having edges lined with transparent strips. (See page 8, § 10.)

**Triangles (M).** (a) 1 7″ transparent triangle, 45°. (See page 10, § 11.) (b) 1 10″ transparent triangle, 30°–60°. (See page 10, § 11.)

**Irregular Curve (M).** 1 transparent irregular curve. Similar to K. & E. #21 or Dietzgen #20. (See page 13, § 12.)

* The instruments or materials marked (L) are required in lettering; (M) in mechanical drawing; (S) in sketching; (A) in all courses.

**Pencil Pointer (A).** 1 medium-cut file (see page 14, § 13) or a small pad of fine sandpaper.

**Pencils (A).** (a) 1 4H pencil of hexagon cross section. (See page 14, § 14.) (b) **(M)** 1 6H pencil of hexagon cross section. (See page 14, § 14.)

**Erasers (A).** (a) 1 block of "Artgum" or a sponge rubber. (See page 16, § 15.) (b) Faber's (or equivalent) soft green "Emerald" eraser. (See page 16, § 15.)

**Erasing Shield (A).** 1 metal or celluloid erasing shield. (See page 17, § 16.)

**Soapstone (A).** Small piece of soapstone. (See page 18, § 17.)

**Drawing Ink (A).** 1 bottle of black waterproof drawing ink. (See page 18, § 18.)

**Pens (A).** (a) 1 each of D. Leonardt & Co.'s #506 F. and #516 E.F., ball-pointed pens. (b) 1 each of Gillott #170 and #303; 1 Esterbrook #182 and 1 Spencerian #1. (See page 18, § 19.)

**Penholders (A).** (a) 1 penholder for ball-pointed pens. (See page 20, § 20.) (b) 1 penholder for ordinary pens. Cork-tipped holders preferred.

**Drawing Instruments (M).** 1 set of drawing instruments of *good* design and quality, consisting of at least the following:

(a) Ruling pen, 5″ instrument of *best* quality. (See page 20, § 21.)

(b) Compass, 5″, pivot-jointed instrument (see page 23, § 22) with handle, lengthening bar, detachable pencil and pen legs.

(c) Dividers, 5″ instrument with hair-spring adjustment. (See page 26, § 23.)

(d) Bow dividers having a maximum capacity of $1\frac{1}{4}''$ radius. (See page 27, § 24.)

(e) Bow pencil having a maximum capacity of $1\frac{1}{4}''$ radius. (See page 27, § 25.)

(f) Bow pen of *best* quality and having a maximum capacity of $1\frac{1}{4}''$ radius. (See page 28, § 26.)

(g) Case for set of drawing instruments.

**Scale (M), (S).** 1 architect's 12-inch triangular boxwood drawing scale, graduated as follows: $\frac{1}{8}''$, $\frac{1}{4}''$, $\frac{3}{8}''$, $\frac{1}{2}''$, $\frac{3}{4}''$, 1″, $1\frac{1}{2}''$, 2″, 3″, 4″, and one "edge" graduated in inches and sixteenths of an inch. (See page 29, § 27.)

**Protractor** (M). Not absolutely necessary in this course. (See page 31, § 28.)

**Machinist's Calipers** (S). (a) 1 pair 6″ outside spring-calipers. (See page 32, § 29.) (b) 1 pair 6″ inside spring-calipers.

**Machinist's Scale** (S). 1 2-foot length machinist's scale. Not absolutely necessary in this course. (See page 32, Fig. 36.)

**Machinist's Dividers** (S). 1 pair 6″ machinist's dividers. Not absolutely necessary in this course. (See page 33, § 29.)

**Blotter.** 1 ordinary 4″ × 9″ blotter. (See page 33, § 30.)

**Pen Wiper** (A). 1 piece of linen cloth about 9″ × 9″. (See page 33, § 30.)

**Instrument Cleaner** (A). 1 piece of cotton cloth about 18″ × 18″ for brushing off drawings and cleaning instruments. (See page 33, § 30.)

**Manila Covers** (L), (S). 3 standard (#10) Manila covers.

**Paper Fasteners** (A). 1 dozen #3 brass paper fasteners with washers.

**Carbonate of Soda** (M). Small quantity of soda for making changes on blue-print paper.

3. **Drawing Paper.** In selecting paper to use for any particular drawing, the character of the work and the purpose for which the drawing is to be made are the determining factors.

In general a **good drawing paper** should be tough, strong, and of uniform thickness. It should not become brittle or discolored with age, and should not wrinkle nor warp during changing weather. The surface should stretch evenly and admit of considerable erasing without injury.

**For inked drawings,** the surface of the paper selected should neither repel nor absorb liquids. If the paper repels ink the lines will be irregular and uneven. An illustration of this is seen if an inked line is drawn on oily paper. If the paper absorbs ink, the line will spread and resemble a line drawn upon blotting paper. **For pencil drawings,** paper with an unpolished surface should be selected, since it will take a pencil mark more readily than paper with a polished surface and does not require the same care in making erasures. There is little difference in

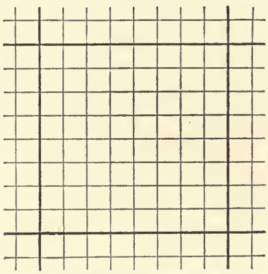
the two sides of good drawing paper, but the side from which the "water-mark" reads correctly is meant to be the working side.

A cheap grade of **Manila paper** will do for such pencil work as shop drawings, preliminary sketches, drawings to be traced, and in general all drawings not requiring extreme accuracy nor intended to be of permanent value. A better grade of paper should be used for work of a more exacting character.

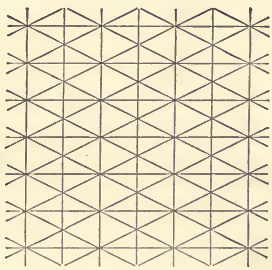
**Whatman paper** is used extensively for making permanent ink drawings. There are two grades suitable for this purpose; namely, hot pressed and cold pressed. The hot pressed (marked H.P.) has a smooth surface, and is used principally for fine-line drawings. The cold pressed (marked N. to signify *not* hot pressed, and sometimes marked C.P.) is used extensively for tinted and water-color work.

4. **Ruled Paper.** In the study of free-hand lettering and in sketching, the beginner can save much time and secure greater accuracy by using **specially ruled paper,** the advantage being that proportion can be obtained *without* the aid of measuring instruments.

Fig. 1 (a) shows **cross-section ruling,** the small squares being one-eighth inch, and every eighth line is extra heavy so that the one-inch squares stand out prominently. This paper is used in ordinary sketching, etc.



(a) Cross-Section Ruling.



(b) Isometric Ruling.

Fig. 1.—Ruled Paper.

Fig. 1 (b) shows **isometric ruling,** which is used in making isometric *perspective* sketches.

Care must be exercised in **cleaning drawings made on cross-section paper,** as cleaning with either the eraser or the "artgum" tends to dim the section lines and thus spoil the work.

Make all lines *light weight* and with a medium soft pencil then retrace the lines that are to be permanent and clean the drawing. This method insures the least amount of erasing.

**5. Tracing Paper.** Tracing paper is a thin, transparent paper which is used for making tracings that are usually (but not always) to be of a temporary character. It is cheaper than tracing cloth, but inferior to it in permanency. Blue prints made from drawings on tracing paper require longer exposure and are not so distinct as those made from drawings on tracing cloth.

**6. Tracing Cloth.** Tracing cloth is a specially prepared linen, having one side finished with a smooth glazed surface and the other dull finished. Either side will take ink and there is a difference of opinion among draftsmen as to which is the better side to work on. **The glazed side** is better for lettering and free-hand work in general, as there is less tendency to catch the pen point and cause blotting; also, since the glazed coating holds the ink and keeps it from soaking into the fibers of the cloth, it is easier to erase ink from this side. The chief disadvantages are that the glazed side does not take the ink quite so readily; also the tracing tends to curl up when the inking has been done on the glazed side. **The dull side** takes ink more easily, and if any lines are to be penciled directly on the cloth (as in making alterations, additions, etc.) the rough surface of the dull side takes these lines more readily. For the same reason the dirt collects from the triangles and T-square. **The glazed side is recommended** for beginners and with experience the draftsman will determine his preference.

In cutting the tracing cloth (called for in the list of necessary supplies) into sheets for use, see that each sheet is large enough to permit of cutting off the margin containing the thumb tack holes when the tracing is finally trimmed to the standard size (12″ × 18″). Also, in cutting the cloth, care must be exercised to avoid breaking its surface, as creases and broken places render the cloth unfit for use.

Only a good quality tracing cloth should be used.

**7. Blue-print Paper** is a specially prepared paper, having one side coated with chemicals which are sensitive to light and which will turn a rich permanent blue after the paper has been exposed

to the light and washed in clean water. Blue-print paper is seldom prepared in the drafting room since it can be bought cheaper in the open market. A formula for preparing blue-print paper is as follows:

$2\frac{1}{2}$ ounces Red Prussiate of Potassium in 1 pint of water.

4 ounces Citrate of Iron and Ammonia in 1 pint of water.

Dissolve thoroughly and filter; then mix and apply evenly on one side of the paper with a sponge or a broad, thin brush. The paper must be prepared in a dark place and must be stored in a dark dry place.

**8. Drawing Boards.** A drawing board should be made of a light weight material which is not greatly affected by changes of weather, and which will take the thumb tacks easily and hold them securely. Also, the board should be designed to allow for, or resist as far as possible, any change in shape due to warping or handling. The best material for a drawing board is thoroughly seasoned, soft, white pine, free from knots or pitch. The best design depends largely on the size of the board.

The board recommended for use in this work, both as to design and size, is shown in Fig. 2. This board consists of a

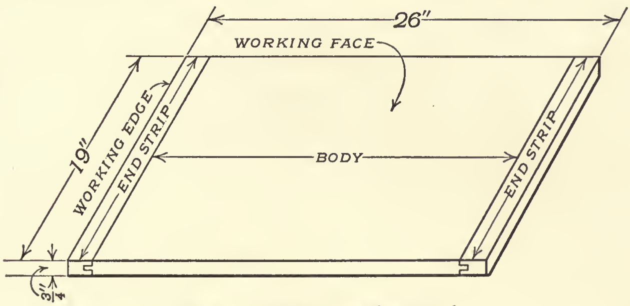



Fig. 2.— Ordinary Drawing Board.

central portion or " body," in which part the grain should run lengthwise, and " end strips " so placed that the grain runs at right angles to that of the body.

The body and end strips are united by a glued tongue and grooved joint. In some instances the end strips are made of hard wood in order to better resist warping or being nicked in handling. This construction will resist excessive warping in

small boards, but the larger sizes are usually made with a pair of hard-wood ledges screwed or dovetailed to the back, and in addition there is a series of saw grooves cut lengthwise on the back of the body of the board.

The drawing board should be covered with a light coat of shellac to protect it from moisture and to keep it clean.

The top surface is termed the **working face** (see Fig. 2, page 7), and should be a perfectly smooth plane. The left-hand edge is termed the **working edge,** because it acts as a guide for the T-square head. The working edge should be perfectly straight and smooth and free from nicks. The straightness of **the working edge should be tested occasionally** by placing a standard straightedge, or the edge of a T-square blade which is known to be perfectly straight, along it to see if the two coincide throughout.

**9. Thumb Tacks.** For all ordinary work the drawing paper or tracing cloth is secured to the drawing board with thumb tacks. These tacks are inexpensive and only the best should be used. A good form is shown in Fig. 3.

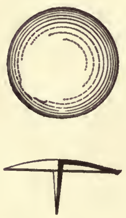


Fig. 3. — Ordinary Thumb Tack.

The tack should be small and the outer edge of the " head " should be thin so as not to interfere with the free use of the T-square and triangles; as a rule, small thumb tacks are preferable, say $\frac{5}{16}''$ diameter.

**One tack should be used at each corner** of the sheet, and if the drawing or tracing is large, enough thumb tacks should be placed along the edges to hold the paper or cloth securely on the drawing board. Tracing especially can be done much more rapidly if the cloth fits closely to the paper drawing.

**10. T-Squares.** The T-square derives its name from its resemblance to the letter T and from its use in " squaring " the paper on the drawing board. It is intended primarily to serve as a ruling edge in drawing horizontal lines (that is, lines perpendicular to the working edge of the drawing board), and to provide an edge for guiding the triangles in drawing vertical or inclined lines.

In its simplest form (see Fig. 4) the T-square consists of a thin "blade" securely fastened at right angles to a thicker and shorter piece termed the "head."

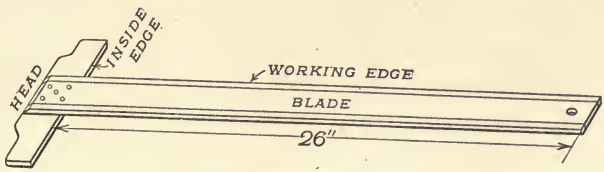



Fig. 4. — Ordinary T-Square.

In a more elaborate design the head is pivoted so that it can be adjusted and fastened at any angle with the blade. This arrangement enables the draftsman to use the working edge of the drawing board to guide the T-square in drawing a series of parallel lines that are *not* perpendicular to that edge. While this "swivel head" is sometimes an advantage, it is not necessary for ordinary use and the design shown in Fig. 4 is recommended.

T-squares are made of wood, rubber and metal, the most satisfactory being made of wood and having the edges of the blade lined with a narrow strip of transparent amber or celluloid. The blade should be as long as the drawing board, and it is desirable to have the blade and the head exactly at right angles in order that the lines drawn with the T-square will be at right angles to the working edge of the drawing board. This, however, is not absolutely necessary, for if the working edge is straight and the T-square is properly used, the lines are always drawn with reference to the working edge of the board, and are therefore parallel, and the drawing will be accurate.

The T-square should be polished or given a coat of shellac in order that dirt may not adhere to its surface; for unless the blade is perfectly clean it will soon soil the drawing in rubbing over it.

**To test the straightness** of the working edge, use a pencil having hard lead sharpened to a fine chisel edge (see page 15, § 14); hold it against the working edge of the T-square and draw a line the full length of the blade. Turn the blade over (i.e., revolve about the lines just drawn) so as to bring the opposite side against the paper, and if the working edge does not coincide with

the line throughout its entire length, this edge is not "true." The inside edge of the T-square head may be tested by applying any standard straightedge to it.

**Care must be taken** that the blade is not loosened, and that the working edges are perfectly straight and free from nicks. The T-square must not be used to hammer thumb tacks into place, and the top or working edge of the blade must *never* be used to guide the knife in cutting paper or tracing cloth, as the smallest nick will disfigure all lines drawn by the aid of that portion of the blade. The *lower* edge of the T-square, however, may be used as a straightedge for trimming drawings or cutting paper.

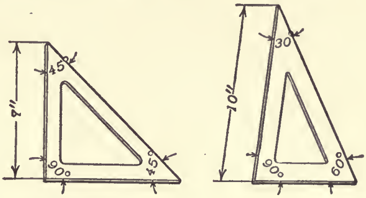
**To use the T-square,** hold it near the center of the head with the left hand, and, with a steady but *unstrained* grip, slide the inner face of the head along the working edge of the drawing board until the top edge of the blade is in the proper position for drawing the line or guiding the triangle. The lower edge of the blade should never be used in this way, as it may *not* be parallel to the working edge, and as a result all lines drawn would not be parallel.

The habit should be cultivated of "feeling" that the T-square is in perfect contact before drawing a line. That is, the head should set firmly against the working edge of the drawing board and the blade should lie perfectly flat on the drawing.

11. **Triangles.** Triangles are used as a guide for the ruling pen or the pencil in drawing lines at an angle to the T-square blade. All the angles of a triangle must be true and its edges straight and free from nicks. The material of which it is made should not warp easily, or show tendency to gather and hold dust; it should be light enough to be easily handled and hard enough to hold its edge under use. Triangles are made of wood, rubber, amber, celluloid, or metal. Metal triangles are accurate and durable, but are difficult to handle, and if dropped on a drawing the corners puncture the surface. Those made of wood are cheap and light in weight, but warp easily and are hard to keep clean. The triangles made of transparent amber or celluloid meet most of the requirements of a first-class instrument

and are to be preferred. An additional advantage is that, due to their transparency, the draftsman is enabled to see work already completed although it may be covered with the triangle.

The triangles most generally used are the 45° [see Fig. 5(a)] and the 30°–60°, or what is generally called the 60°, triangle [see Fig. 5(b)].



(a) 45° Triangle. (b) 60° Triangle.
Fig. 5.— Ordinary Triangles.

The most desirable size of triangle to use depends largely on the work to be done, but the working edges should be long enough not to require working too close to the corners, since they become rounded with use and are therefore inaccurate. Accuracy in triangles is of the greatest importance and they should be tested when purchased as well as occasionally thereafter, as they may lose their accuracy by use. In testing the accuracy of the triangles, use a 6H pencil with lead sharpened to a fine chisel edge. (See page 15, § 14). **All edges of the triangle should be first tested** for straightness by holding them against an accurate straight-edge, or by the method given for testing the T-square blade (see page 9, § 10) and then the angles should be tested.

**To test the 90°** angle for accuracy, place one of the *short* sides of the triangle against the working edge of the T-square blade and, with the chisel edge of the pencil held *close* to the triangle, draw a vertical line. Next turn the triangle over (i.e., revolve it about the line just drawn) so as to bring the opposite side against the paper, and, using the same edge as a guide for the pencil, draw a second vertical line through a point at either extremity of the first line. If these two lines do *not* coincide throughout, the 90° angle is not accurate.

**To test the 45°** angle for accuracy, place one of the *short* edges of the triangle against the working edge of the T-square blade, and, using the longest edge of the triangle as a guide for the pencil, draw a line. Next turn the triangle over so as to bring the opposite side against the paper, and revolve it until the second short edge is against the working edge of the T-square blade, and, again using the long edge of the triangle as a guide for the pencil,

draw a second line through a point at either extremity of the first. If the two lines do *not* coincide throughout, the 45° angle is not accurate.

**To test the 30° and 60°** angles for accuracy, draw a horizontal line with the T-square, then place the *shortest* side of the triangle against the working edge of the T-square blade, and, using the *longest* edge as a guide for the pencil, draw a line to intersect the first line. Next turn the triangle over (i.e., revolve it about the line drawn) so as to bring the opposite side against the paper; with the same short side against the T-square, again use the longest edge as a guide for the pencil, and construct a triangle by drawing a third line to intersect the other two. If all three sides of the triangle drawn are not of equal length, the 30° and 60° angles are not accurate.

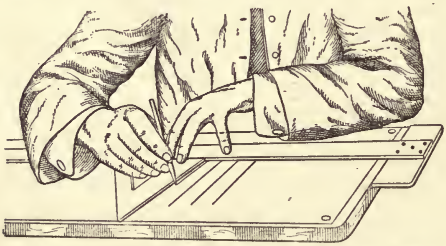


**Fig. 6.—Using the Triangle in Connection with the T-square.**

Fig. 6 shows the **method of using the triangle** in connection with the T-square, the left hand manipulating and holding the triangle and the T-square.

The draftsman should arrange his work so as to avoid being in a *strained* position, and the light should come from a direction that will not cause the T-square and triangle to cast a shadow along the edges being used as a guide to the pen or pencil.

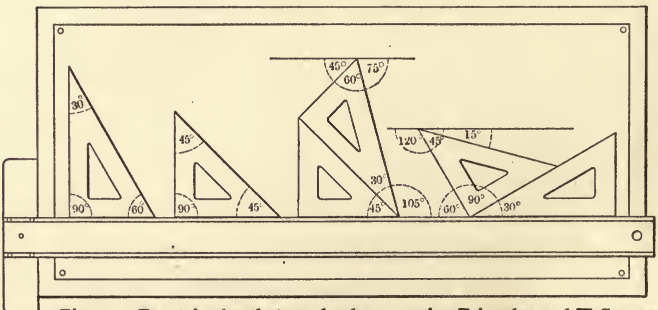



**Fig. 7.—Exact Angles that can be drawn, using Triangles and T-Square.**

**Fig. 7 shows the angles that can be accurately drawn** by using the 60° and 45° triangles and T-square.

A triangle should *not* be used alone in drawing lines parallel or at a given angle with one another, but should be guided by the working edge of the T-square or another triangle. **Fig. 8 shows the method of drawing parallel lines,** using one triangle as a guide for the other. In a similar manner the T-square blade can also be used as a guide for the triangle to draw a series of parallel lines at any angle.

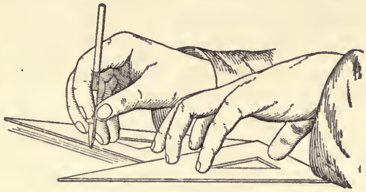


Fig. 8. — Drawing Parallel Lines using one Triangle as a guide to another.

12. **Irregular Curves.** The irregular or French curves are used as a guide to the pen or pencil in drawing curved lines that cannot be conveniently or accurately made with the compasses.

French curves are made of the same materials as triangles, and the remarks on materials for triangles, therefore, apply to French curves (see page 10, § 11). They may be had of many different shapes, but those shown in Fig. 9 probably have the widest use.

Fig. 9. — Ordinary Irregular (French) Curves.

**To use the French curve,** locate a series of points on the line to be drawn, and carefully sketch a *very light* free-hand pencil line through them; next place the French curve so that its edge coincides with the *longest* segment of the free-hand line possible, and draw this segment of the line by using the edge of the curve as a guide. The French curve is then shifted to coincide with another part of the line and the process repeated until the entire curve is drawn. Great care must be taken that the segments are well joined and that the entire line appears *uniform and continuous.* In inking such a curved line, the blades of the pen must at all times be tangent to the curve; otherwise the line will not be of uniform width. In drawing an irregular curve, especially when inking, it is best to first leave a slight break between segments and then, by a separate operation, join all segments so that the curve is continuous and the joined points do not show.

**13. Pencil Pointer.** A small *medium cut* file, with the end flattened to an edge and curved (see Fig. 10), serves the double purpose of a tack lifter and pencil pointer.

**Fig. 10. — Combination Pencil Sharpener and Tack Lifter.**

**In using the file** it should be frequently tapped to remove the lead filings. While filing the lead or tapping the file, care must be taken that the filings do not fall on and smear the drawing.

**14. Lead Pencils.** The essential qualities of a good pencil depend somewhat on the work to be done, but the lead should always be smooth and free from grit, making a clear-cut, distinct mark as sharp as an inked line, yet one which can be easily and completely erased. To meet all requirements lead is made in different degrees of hardness, and the grade selected will depend upon the kind of work to be done and the nature of the surface on which the drawing is made. Should the lead be *too soft*, the lines will smear, especially if the drawing is subjected to considerable handling; whereas if the lead is *too hard*, considerable pressure on the pencil point is necessary to make a visible line. This indents the paper, and erasing and changing of such lines are difficult and unsatisfactory.

Manufacturers usually indicate the degree of hardness of the lead in a drawing pencil by the capital letter **H,** which is repeated as often as necessary; thus, an **H** pencil is the softest, then comes **HH,** then **HHH,** etc.

The **HHHH** (called 4H) pencil is a satisfactory grade for such work as putting in dimensions, arrowheads, lettering, making sketches, and in general for free-hand work.

The 6H pencil is a satisfactory grade for making mechanical drawings.

The degree of hardness of the lead in some cases is indicated by a number, beginning with No. 1 for the softest, the numbers progressing as the degree of hardness increases.

Drawing pencils of either a hexagonal or round cross section are made but the hexagonal pencil is to be preferred since it is not so liable to roll off the drawing board.

To do satisfactory work **the pencil must be kept well sharpened,** and it is important that the beginner learn the best method of keeping the pencil in condition. The lead may be given either the round "cone point" or the flat "chisel edge." Each of these forms has its particular use and it is often an advantage to have both ends of a pencil sharpened, one end having the cone point, the other the chisel edge.

The cone point is used by many draftsmen for all ordinary drawing, and is absolutely necessary for lettering, dimensioning, locating points on a drawing, and all free-hand work.

The following **method of sharpening a pencil** gives a point that will "stand up" well under use.

With a sharp knife, make a long, sloping cut (about seven-eighths inch in length), removing sufficient wood to expose a cylinder of lead, say, about three-eighths inch long. (See Fig. 11).

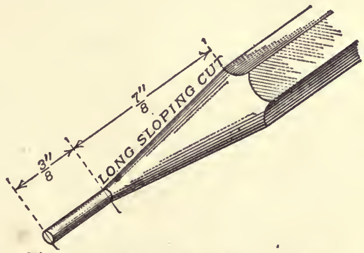



**Fig. 11. — Pencil sharpened to Lead Cylinder only.**

Hold the pencil at an angle with the surface of a file (or a piece of fine sandpaper), and draw the lead across the rough surface, at the same time rotating the pencil in such a way that the lead is worn to a cone shape of the longest slope possible, but do *not* file to a sharp point.

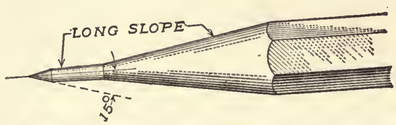



**Fig. 12. — Pencil Lead sharpened to Long Cone and to Point.**

Next raise the pencil to an angle of about 15° and file the end of the lead away until pointed. The pencil point should then appear as shown in Fig. 12.

A few strokes across the file at frequent intervals will keep the pencil lead in good working condition, and the long slope of the lead saves cutting away the wood *every* time the pencil point is sharpened.

The disadvantage of a cone point is that it wears away very rapidly, and to be kept in good shape must be frequently re-pointed. When a number of long, *continuous* lines are to be

drawn, many draftsmen prefer to use a chisel edge (see Fig. 14). **To form a chisel edge** cut away the wood as explained above. Next hold the pencil so it will not rotate, and at such an angle that by drawing it across the file the lead is worn to a beveled surface of the longest slope possible. Do *not* file to the center of the lead before turning the pencil over to file a similar beveled surface on the reverse side (see Fig. 13). At this stage the pencil should *not* have a sharp edge. Next raise the pencil to an angle of about 15°, and by moving back and forth, at the same time slightly rolling, file the tip on one side, and then on the other side, until a rounded chisel edge is produced. (See Fig. 14.)

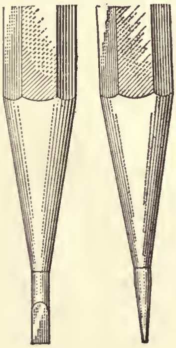


Fig. 13.—Pencil Lead sharpened to Rough Chisel Form but not to Edge. (Front and Side View.)

The lead point must never be moistened, as lead softens from moisture, and then produces a smeared line which cannot be satisfactorily erased.

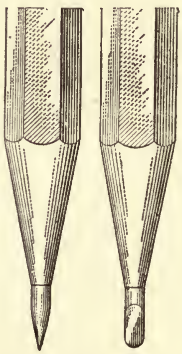


Fig. 14.—Pencil Lead sharpened to Working Chisel Edge. (Side and Front View.)

**To put a chisel edge on the lead of the bow pencil or compass,** fasten the lead in the instrument so that it projects about one quarter of an inch, and file to a chisel edge as explained above, always keeping the edge of the lead perpendicular to the radius of the instrument, that is, tangent to the arcs to be drawn.

15. **Erasers and Erasures.** Erasers are used for removing pencil or ink lines and for cleaning the drawing.

The pencil eraser should be made of soft, fine-grained rubber, free from sand or grit, and of a texture that will not glaze, smear, or injure the surface of the drawing.

The ordinary ink eraser is hard and gritty but should be flexible. Ink erasers often contain so much grit that they injure the surface of the drawing, and for this reason many draftsmen prefer a fine-grained, soft eraser that can be used for both pencil and ink erasing.

**For cleaning drawings** sponge rubber, kneaded rubber, and "artgum" are used. The eraser should be entirely free from grit and soft enough to wear away rapidly, so that it will not mar or scratch the surface of the paper or injure the lines of the drawing and will constantly present a *clean* rubbing surface.

In **making an erasure,** rub over the line with a light pressure until it disappears; then brush off the particles of rubber and paper with a *clean* rag so that the drawing will not become smeared. Beginners are liable to press too heavily when erasing, thinking thereby to save time. This should not be done as it injures the surface of the drawing. Neither should erasing be done so rapidly that the colored rubber heats and streaks the work. The surface of the drawing is liable to injury if a knife edge is used to scratch out lines. If the surface of the paper or cloth is injured in erasing, it can be improved by rubbing briskly over the injured area (which must be perfectly clean) with a smooth, hard surface (such as the bone handle of a pocket-knife) until the surface has become smooth. Soapstone may also be effectively used for this purpose. (See page 18, § 17.)

An eraser should be perfectly clean when used, and if the rubbing surface does not wear off fast enough to keep clean, the eraser end should be rubbed upon some clean spot of the drawing board until it is free from dirt.

Never attempt to make an erasure on a drawing which is not *securely* fastened with thumb tacks, for if held down only with the fingers, the drawing frequently slips and it is liable to be spoiled by being creased or wrinkled.

**As little erasing as possible should be done** when making a drawing to avoid injuring the drawing surface.

**16. Erasing Shield.** When erasing a line, letter, or dimension, care must be taken that the *surrounding* work is not injured. To prevent injury, thin sheets of flexible metal or transparent celluloid, provided with slots and holes of various shapes and sizes, are used to protect the drawing while making erasures over a limited area through these openings. Fig. 15 shows the ordinary

Fig. 15.— Ordinary Erasing Shield.

form of erasing shield. It is important that the shield always be kept clean on *both* sides, otherwise when using it the drawing is liable to become smeared.

**17. Soapstone.** Soapstone is a soft mineral (a compact, granular variety of talc) which gets its name because of its soapy feel. If the surface of paper or tracing cloth has been injured in erasing, it may be improved by rubbing soapstone over the injured portion and polishing with a clean, dry rag.

**18. Drawing Ink.** Drawing ink differs from the ordinary ink used for writing, in that it is heavier and has no penetrating qualities, but merely lies upon the surface of the paper or cloth.

**The requirements of a good drawing ink** are that it will flow freely, dry readily, and will not gum; it must contain no chemicals that will have an injurious effect upon the instruments or paper, and it must be absolutely waterproof. To be waterproof means that the ink will not redissolve *after* drying, and the lines drawn with it will not become blurred or defaced when exposed to moisture.

Drawing ink of practically any color can be obtained, but **only black ink should be used in making working drawings** unless there is some special reason for using inks of other colors. Red ink is used occasionally for making dimension lines, center lines, etc., but this is considered bad practice, as the ink becomes faded with age, and in the case of a tracing the lines will not be sufficiently opaque to print well.

The use of bottled India ink is almost universal in modern drafting-room practice. Drawing ink gradually thickens due to evaporation and the bottle should therefore be kept tightly closed when not in use. When the drawing ink becomes too thick it may be thinned by adding a few drops of diluted ammonia or distilled water.

If the stopper and filler are left out of the bottle, the ink will dry upon them, and the solid particles of dry ink will form small clots, which may be transferred to the pen and obstruct the free flow of the ink.

**19. Ordinary pens.** Four styles of pens are found in drafting rooms: (1) the ordinary writing pen with *fine* point; (2) the or-

dinary writing pen with *stub* point; (3) the *ball-pointed* pen; and (4) the *crow-quill* pen. The *style* of pen selected is largely determined by the width of the lines to be made. An *expert* draftsman can use the ordinary **fine-pointed writing pen** for almost all classes of work, but the beginner will find it easier to make relatively heavy lines with the stub-pointed or the ball-pointed pen.

**The ball-pointed pen** is designed to glide smoothly in any direction and at the same time make a line of *uniform* width. It has little tendency to catch in the surface and splash the ink, and therefore permits of greater freedom in *any* direction and order of strokes when lettering or making free-hand lines.

**The crow-quill pen** is not satisfactory for ordinary work, especially for tracing, as the tendency is to make the lines so fine that they will not reproduce in printing.

A good general rule to follow in **selecting a pen** is that, when perfectly clean and carrying a reasonable quantity of ink, it will make a line of the desired width without requiring a pressure great enough to open the point.

The pen selected is largely a matter of individual preference, and experience will soon dictate the best pen for the different kinds of work. Until the beginner has had sufficient experience to make an intelligent selection, only those pens called for in the list of supplies should be used. (See page 3, § 2.)

**A new pen often gives trouble** from two causes: (1) the flow of the ink may not be free and uniform; (2) the point may be stiff and catch in or scratch the surface. The coating of oil which has been put on the pen by the makers, to prevent rusting, is usually the cause of the ink's not flowing freely on a new pen. This oil can be removed by moistening and thoroughly wiping the pen several times, or by rubbing the pen with finely pulverized crayon or tracing-cloth powder. Dried ink on the pen point will also give trouble and for this reason the pen should be thoroughly cleaned each time before dipping for a new supply of ink.

If the pen is stiff it may be improved by slightly *drawing the temper*. This is done by holding a lighted match to the point, care being taken not to overheat it.

If the pen point catches in or scratches the drawing it should be *rounded* by a few light strokes on an oilstone or on a piece of very fine emery cloth.

A new pen always requires "breaking in" and for this reason an experienced draftsman will take as much care in preserving his pen as if it were one of his more costly instruments. Before putting the pen away always clean it thoroughly with a rag free from lint. Common writing ink should not be used on a pen intended for drawing, as it corrodes the pen and renders it unfit for further use with drawing ink.

**20. Penholders.** The penholder should hold the pen securely and firmly and should be of such a size and shape that the hand will not be cramped. Holders of small diameter are therefore unsatisfactory. The cork-tipped holder has the double advantage of being easy on the fingers and of absorbing moisture.


Fig. 16. — Ordinary Ruling Pen.

**21. Ruling Pens.** The simplest, and probably the best, form of ruling pen consists of two "blades" made of a *single* piece of metal and fastened to a handle, as shown in Fig. 16. In order to hold a fine edge the blades must be made of the best tempered steel. The inner blade (into which the screw is tapped) should be almost straight. The outer blade should be slightly curved, so that, when the points are together, there exists a cavity of sufficient capacity to hold enough ink to do a reasonable amount of work and not evaporate too rapidly as it would if the film of ink were very thin. The "nibs" must be even in length and terminate in a slightly rounded point; they must have a moderately sharp edge, and must be broad enough not to wear away too rapidly. The handle should not be made of a material which breaks easily.

The adjusting screws of all instruments should have an occasional application of light oil to prevent rusting.

**To adjust the pen,** hold it toward the light, or over a piece of white paper, so that the space between the nibs can be seen; then

turn the thumb-screw until this distance is the width of the line to be drawn. **To fill the pen** (see Fig. 17), use the filler that is attached to the stopper of the ink bottle, and let the ink flow between the nibs until it is nearly one-quarter of an inch from the points.

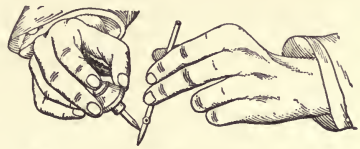


Fig. 17. — Charging Ruling Pen with Ink.

While filling the pen never hold it over the drawing as ink is often dropped during the process. After the pen has been filled, see if any ink has gotten on the outside of the nibs, and if so, wipe them off with a clean rag (see page 33, § 30).

**To use the pen** (see Fig. 18), hold it with the thumb and the first two fingers, so that the thumb-screw is *away* from the body, and the pen perpendicular to the surface of the drawing. The third and fourth fingers should rest lightly on the triangle or T-square blade, to steady the hand and control the pressure of the pen against the drawing. This pressure and the speed at which the pen is moved along the ruling edge must not vary, or the line will *not be uniform* throughout its length. The pen may be inclined slightly in the direction in which the line is being drawn, so that, in moving, the point is pulled after the body of the pen; but under no condition should it be inclined in the opposite direction, making it necessary to push the point in advance of the body of the pen. Move the pen from left to right in drawing lines, which are horizontal or nearly so, from bottom to top in drawing lines which are vertical or nearly so, and in either direction (depending upon the angle) in drawing inclined lines (see Fig. 19). Always hold the pen so that a line of the least width is drawn for a given setting of the nibs. In no case is the ruling pen to be used in making *free-hand* lines as this is liable to injure the nibs.

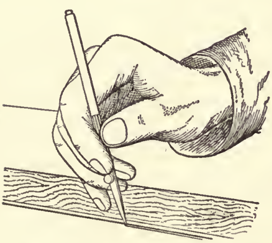


Fig. 18. — Using the Ruling Pen.

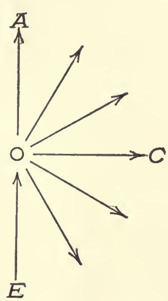



Fig. 19. — Direction in which to draw Ruled Lines.

The blades of all pens must be kept absolutely clean, both inside and out, if good results are to be obtained. More unsatisfactory work results from the neglect of this precaution than from any other. No pen can be expected to make a good line when the blades are incrusted with dried ink. Ink corrodes the metal points, as shown by the magnified view in Fig. 20, and the pen is finally rendered unfit for use.

Fig. 20.—Ruling Pen Blade corroded (magnified).

As soon as the ink in the pen begins to thicken, pass a strip of paper or cloth between the blades, and refill the pen; but never refill without first cleaning the inner surface of the blades.

**To clean the inner surface of the blades,** fold a piece of unglazed paper, or the rag penwiper, until thick enough to spring the nibs slightly when passed between them. Draw the paper or cloth between the blades, from the screw to the tip, several times, or until it shows no ink, even after being moistened. (See Fig. 75, page 110.) Besides frequently cleaning the pen while in use, the blades should be opened wide and given a thorough cleaning with the instrument wiper before it is put away.

The points of the pen will wear dull after it has been used for some time, and in order to again make a clear-cut line they must be resharpened.

**To sharpen the ruling pen,** first clean thoroughly and then close the blades until they nearly touch. This can be judged by properly holding the pen to the light or over a piece of white paper. Next, keeping the pen perpendicular to the surface of a flat, close-grained oilstone, move back and forth until the nibs are "square" and of equal length. The nibs are then rounded to a radius of one thirty-second of an inch by ruling a line on the oilstone and continually changing the inclination of the pen, as shown in Fig. 21. This process dulls the edge of the points and they must then be sharpened by slightly opening the blades and rubbing the *outer* surface of the nibs on the oilstone. Care

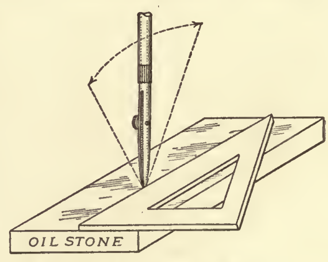



Fig. 21.—Rounding the Nibs of the Pen.

must be taken that the rounded shape of the end is not altered; also a "wire edge" must not be produced, as this will cut the surface of the paper or tracing cloth.

**To test the condition of the pen,** clean it thoroughly and draw a light and heavy inked line; if both are not clear-cut and even, the pen requires attention.

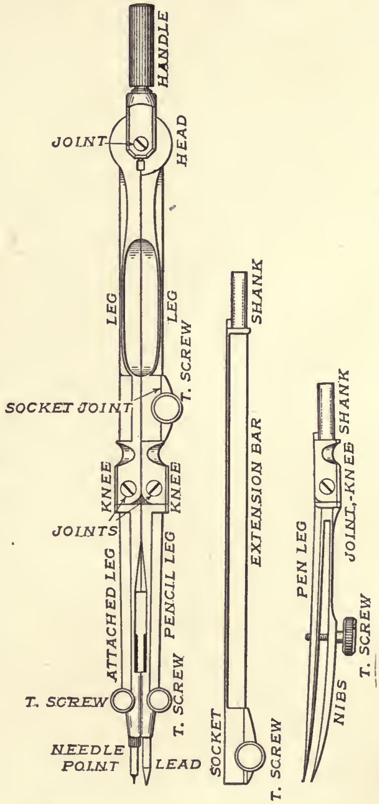



Fig. 22.—Compass Outfit Complete.

**22. Compasses.** The compass is used in drawing circles and arcs of circles. A complete compass outfit (see Fig. 22) consists of five parts: (1) the "head piece"; (2) the "needle point"; (3) the "pencil leg"; (4) the "pen leg"; (5) the "extension bar."

The instrument may be made of iron, brass, steel, aluminum, or German silver, the best being made of *rolled* (not cast) German silver. It is difficult to determine the quality of German silver by inspection, but the cast material can usually be detected by its high *glossy* finish.

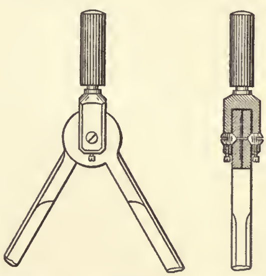
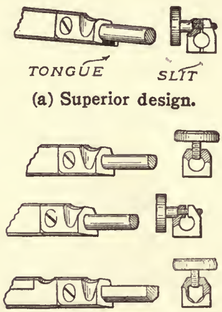


Fig. 23.—Head-Joint Design.

The design of the compass should be such that the "head" and "knee joints" allow free movement of the parts and at the same time give proper rigidity. They should be so designed as to exclude dirt and moisture and should fit accurately. The socket joints should fit the shank accurately, hold the leg in proper alignment, and have a clamping device that will hold the interchangeable parts rigid. Fig. 23 shows the details of a good design for the head joint.

The legs are alike at this joint, and two pivoted screws are inserted in the yoke of the handle to hold the legs in position; small set screws prevent the pivoted screws from turning in the yoke. All contact surfaces are made circular, which insures a close fit for all positions of the legs, and thus excludes dirt and moisture.

Several forms of socket joints are shown in Fig. 24, the design as shown in Fig. 24(a) being the best. The hole is made circular and slightly tapered. The socket is split, and the clamping screw is located on the side.



(a) Superior design.

(b) Inferior designs.

Fig. 24. — Socket-joint Designs.

The handle of the compass is sometimes designed so that no matter in what position the upper portion of the legs are set, it always keeps a central position relative to them, and consequently is approximately perpendicular to the surface of the drawing when the instrument is being used. This is an advantage unless the device is so delicately constructed that the wear and tear arising from ordinary use soon render the entire instrument valueless.

**The needle point** consists of a finely tempered steel wire which fits into a cylindrical socket in the lower end of the attached leg. It should fit the socket with a snug, sliding fit, and be clamped with a thumbscrew. The lower end of the needle point (which enters the drawing) has a shoulder to support the weight and pressure on the instrument when in use and thus prevents a hole being bored in the drawing.

Besides the knee joint and the shank of the pencil leg, the small, cylindrical, split socket that receives the lead, and the clamping device that holds the lead should be examined. The socket should be drilled accurately and of the proper size to receive the lead of an ordinary drawing pencil. The clamping device should exert a uniform pressure along the *entire* length of the socket and hold the lead secure and firm.

The remarks on the design and care of the ruling pen (see page 20, § 21) apply generally to the pen leg of the compass.

The extension bar is used to increase the range of the compass, by making it possible to draw circles of a larger diameter than can be drawn with the compass proper. Its design is determined by the design of the socket joint of the compass.

The joints of instruments should have an occasional application of light oil to prevent rusting and insure easy working.

**To prepare the compass for use,** insert the pen leg in the socket as far as it will go, and then clamp it securely in position. Adjust the needle point so that the point of the pen and the *shoulder* of the needle are even when the compass is completely closed. The needle point is now adjusted for either pen or pencil and should not be changed. As the lead in the pencil wears away, making readjustment necessary, the position of the lead should be changed and not the needle point. The lead is usually sharpened to a chisel edge (see page 15, § 14) which must be tangent to the arc it draws. It is adjusted by clamping the pencil leg in the instrument and adjusting the lead until the end is even with the needle point when the compass is completely closed.

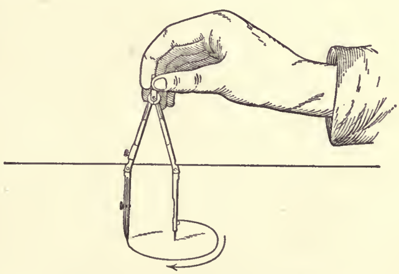


Fig. 25. — Using the Compass.

**To draw a circle,** bend both legs at the knee joints an *equal* amount, and enough to bring the marking point and the needle point each perpendicular to the surface of the drawing when the instrument is being used. This adjustment (see Fig. 25) places the needle point in such a position that it will make the smallest hole possible in the drawing and insures both nibs of the pen bearing evenly on the paper.

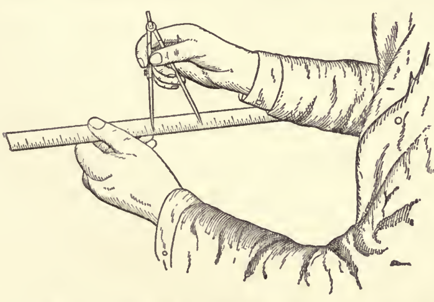


Fig. 26. — Setting or Reading the Instrument.

The proper opening between the points (the radius) may be taken from the measuring scale, as shown in Fig. 26, or the extremities of the radius may be marked from

the scale directly on the drawing in their proper position and the compass set to them, the latter method being preferable as there is less chance of injury to the scale division marks.

To use the compass hold the handle of the instrument lightly between the thumb and the first and second fingers; guide the needle point to the center of the circle by sliding it on a finger of the left hand; hold the compass so that both the marking and the needle points are perpendicular to the surface of the drawing and remain so while making the circle. Place the needle point at the center, and the marking point at the bottom of the circle, and with a slight pressure against the drawing rotate the compass right handed, that is, in the same direction as the hands of a clock move (never the reverse) by rolling the handle between the thumb and first finger.

All inked arcs and circles should be made by one continuous revolution, and where any portion of a line is so thin or ragged as to require retracing, the entire line should be retraced.

The compass should be manipulated with one hand, unless the lengthening bar is used, then the needle point should be steadied with one hand, and the marking point rotated with the other.

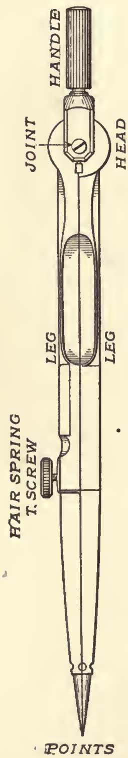



Fig. 27.—Ordinary Dividers.

**23. Dividers.** The dividers (see Fig. 27) are used to transfer distances from one point to another, or to divide lines or circles into equal parts, but they should not be used to transfer measurements from the scale to the drawing when this process injures the division marks on the scale. See page 25, Fig. 26.

Neither should the dividers be used where it is possible to lay off or measure distances accurately with the drawing scale. See page 30, Fig. 32.

In design the dividers are similar to the compass, and the main points considered with reference to the compass apply to the dividers (see page 23, § 22). The legs of the dividers must be of the same length, and the steel points should be conical and sharp. One of the legs should be provided with a hair-

spring, controlled by a thumbscrew, to facilitate delicate adjustment.

**To divide, or step off, a line or circle,** manipulate the dividers with one hand, and, with first one divider point and then the other as a center, rotate the dividers alternately to the right, then to the left as if describing a series of semicircles.

To insure accuracy and neatness, the dividers should never be lifted entirely off the paper while being used, and the points should merely rest on the drawing and not puncture it.

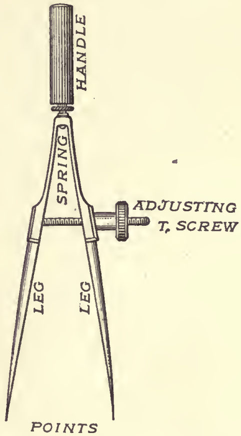
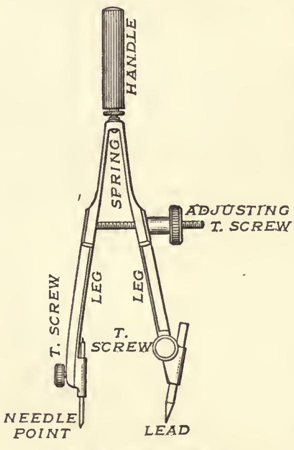


Fig. 28. — Ordinary Bow Dividers.

**24. Bow Dividers.** The bow dividers (see Fig. 28) are used in the same manner and for the same purpose as the large dividers (see page 26, § 23).

The bow dividers when once set maintain a fixed distance or radius and therefore in "stepping off" distances they should be used in preference to the large dividers.

The points to be observed in selecting, using, and caring for the other bow instruments apply largely to the bow dividers (see § 25, this page).

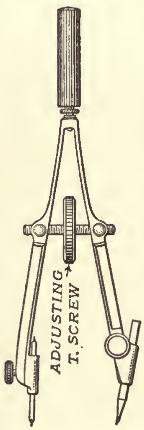


(a) Ordinary Design.
Fig. 29. — Bow Pencils.

**25. Bow Pencils.** This instrument is practically a pencil compass of small radius. In making small arcs or circles it has the advantage of being easier to handle than the large compass, also in drawing several arcs or circles of the same diameter (as for example in representing bolt holes, boiler tubes, fillets, corners, etc.) there is less liability that the distance between the points (that is the radius) will be changed in the handling of the instrument. The ordinary form of Bow Pencil is shown in Fig. 29(a).

The legs of the bow pencil should be made of one continuous piece of steel, finished and tempered; the handle should be made of metal, as ivory and bone handles break too easily; the needle point should be made of tempered steel and should have a well-formed shoulder (see page 24, § 22). The spring should be strong and stiff; the threaded parts cut smooth and true, and the adjusting screw capable of bringing the needle and lead points together.

Another design of spring instruments [see Fig. 29(b)] has a central thumbscrew and a right and left thread working in swivel sockets. The advantage claimed for this design is that the instrument can be set in one half the time required to set the instrument shown in Fig. 29(a). The disadvantages are that the radius is much more liable to change in handling, and the swivel sockets are necessarily delicate, easily injured and wear rapidly.




**(b) Instrument with Center Adjustment.**
**Fig. 29. — Bow Pencils.**

The lead used is the same as for the compass, and it is sharpened and adjusted in the same manner (see page 25, § 22), except for extremely small circles, when the lead should be sharpened to a conical point (see page 15, § 14).

**To set the bow pencil** shown in Fig. 29(a), first make an approximate adjustment by compressing the spring with the fingers and setting the thumbscrew (this will minimize the wear on the adjusting screw thread); then make the final adjustment with the thumbscrew. The bow pencil is manipulated in the same manner as the compass (see page 25, § 22).

An important **test of the bow pencil** is to remove the lead and clamp a needle point in its place (the instrument now has two needle points); then close the instrument, and if the two points meet exactly, the sockets for the lead and for the needle point are accurately drilled and the instrument should do satisfactory work; otherwise work is liable to be inaccurate.

**26. Bow Pens.** The bow pen (see Fig. 30) is used to ink the circles and arcs that have been penciled with the bow pencil.

Its advantages over the compass are the same as those of the bow pencil (see page 27, § 25). The general requirements of the bow pen are about the same as those for the bow pencil, and the remarks on the care, use, and sharpening of the ruling pen apply to the bow pen (see page 20, § 21).

The edge of the pen should be tangent to the circle, being drawn so that a clear cut line of uniform width is made, and when the instrument is closed the needle point should touch the pen at the *middle* of the blade end.

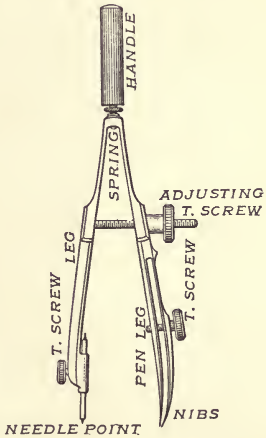


**Fig. 30.— Ordinary Bow Pen.**

**27. Scales.** The purpose of the scale is to make measurements on the drawing, and it should never be used as a straightedge for drawing lines.

There are two drawing scales in general use: the civil engineer's, or, as it is usually called, the "engineer's scale," and the mechanical engineer's, or the "architect's scale." These scales differ in the way their inch spaces are subdivided.

**The engineer's scale** divides the inch into such decimal parts as tenths, twentieths, thirtieths, etc., and is used in such work as map drawing, plotting stress diagrams, measuring indicator cards, and in certain government work.

**The architect's scale** is graduated into duodecimals (twelfths), to correspond to the ordinary foot rule used by the workman in the shop; the duodecimal is divided into halves, quarters, eighths, sixteenths, thirty-seconds, etc., and the scale is used for making all drawings of objects which are to be dimensioned in the ordinary foot-rule denominations. This includes practically all mechanical drawings.

The best scales are made of boxwood and have beveled edges lined with a white material resembling ivory. The division marks and figures are printed in black on this white background, and are very distinct and easy to read. There are two forms of scale in general use: the flat scale with beveled edges, and the

**scale of triangular cross section.** The latter form is shown in Fig. 31 and has the advantage of combining eleven distinct scale divisions on a single instrument.

Scales are made of different lengths, but, in order to be provided with a full-size one-foot rule, the twelve-inch length (not counting the small spaces at each end, which are to protect the end graduations) is recommended. The numerals printed on these end

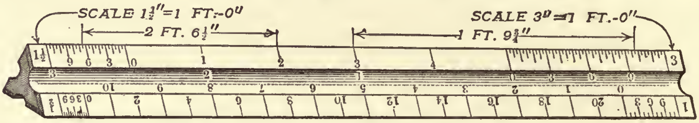



**Fig. 31. — Ordinary Triangular Scale.**

spaces indicate the size of the scale along that bevel; thus the number $1\frac{1}{2}$ on the end of the scale (shown in Fig. 31) denotes that this bevel is divided into spaces one and one-half inches long and is used to make drawings in which a length of $1\frac{1}{2}$ inches represents 1 foot (12″) of the object represented. The *first* inch and one-half length is subdivided into twelve equal parts, and each of these divisions represents one-twelfth of a foot, or one inch. The row of figures 0, 1, 2, 3, etc., indicates the divisions that represent 1 ft., 2 ft., 3 ft., etc. (measuring from the 0 mark), on a scale on which $1\frac{1}{2}$ inches equal one foot. On some scales the length taken to represent one foot is so small that inches cannot be indicated. Thus, on the $\frac{3}{32}$ scale the unit ($\frac{3}{32}''$) is divided into four parts, so that each of these subdivisions represents one-fourth of one foot, or 3 inches, and the eye is relied upon to divide this space, representing 3 inches, into still smaller divisions.

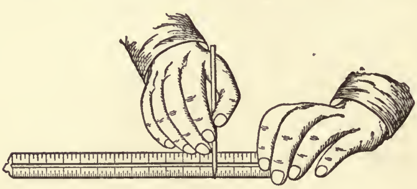


**Fig. 32. — Using the Scale.**

**To use the scale** in marking off a distance, apply it to the drawing so that it lies flat on the surface (see Fig. 32) and in a position to receive the best light possible on the division marks and numerals; then mark the points, defining the distance, with a 6H pencil sharpened to a fine cone point (see page 15, § 14). The scale is applied in a similar manner in measuring distances on a drawing.

Care must be taken not to injure the sharpness of the edge of the scale or the division marks and numerals.

**Measurements should ordinarily be taken directly from the scale** and not transferred from the scale to the drawing by means of a pair of dividers, especially if by so doing the scale divisions become defaced.

Where it is necessary to set an instrument to a measurement, as for example the radius of an arc, the best method is to lay the scale on the paper and adjust the instrument along its edge, so as to avoid scratching or defacing the graduations on the scale with the points of the instrument. Where this method is not accurate, set the instrument as shown in Fig. 26, page 25.

**To mark off a number of consecutive measurements,** such as 2″, 5″, 1″, and ½″, along any straight line, keep the scale stationary, and, beginning at zero, mark off in succession the distances 2″, $2'' + 5'' = 7''$, $2'' + 5'' + 1'' = 8''$, and $2'' + 5'' + 1'' + \frac{1}{2}'' = 8\frac{1}{2}''$. By this method the length of the line is equal to the sum of the lengths of all its parts, and the *accumulation* of error which is likely to result from moving the scale along the line and making each measurement an independent operation is avoided.

**To test the accuracy of a scale,** mark off the divisions to be tested along a straight line. Reverse the scale, and if the subdivisions do not coincide, the scale is inaccurate.

**28. Protractors.** The protractor is an instrument for measuring or laying off angles. It may be made of paper, celluloid, brass, German silver, or steel. The two latter materials are the most satisfactory.

Fig. 33 illustrates the style of protractor in most general use, but more elaborate designs may be had.

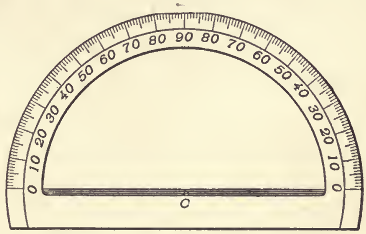



Fig. 33. — Ordinary Protractor.

**To use this protractor,** place it so that the two zero marks coincide with the given line (produced if necessary), and the center (C) coincides with the vertex of the desired angle. The protractor is now in correct position for reading. If a line is to be drawn, making a desired

angle with the given line, use a cone-pointed pencil (see page 15, § 14) and mark a very fine point on the drawing just at the outer edge of the protractor and opposite the desired angle-division on the scale, and a line drawn through this point and the point C will make the desired angle with the original line.

**29. Machinist's Calipers, Dividers, and Steel Rule.** To make a drawing of any existing object, for example a machine, all of the principal dimensions must be obtained. These measurements should always be made with a two-foot rule or a machinist's steel rule and not with the draftsman's scale. Apply the measuring rule as close to the part to be measured as possible. By use of the dividers and the calipers, measurements otherwise inaccessible can often be made. The best calipers and dividers are made of finely tempered steel and are provided with a spring nut (see Figs. 34, 35, and 38) which admits of rapid adjustment.

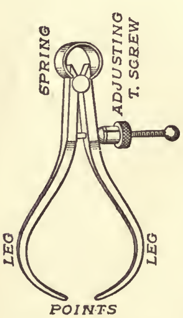


**Fig. 34. — Ordinary Outside Calipers.**

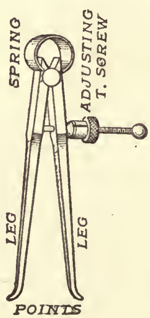


**Fig. 35. — Ordinary Inside Calipers.**

**The outside calipers** (see Fig. 34) are used to determine the diameters of cylinders, the thickness of flat parts, etc., and the **inside calipers** (see Fig. 35) are used to determine the diameters of holes or other inside dimensions inaccessible to the scale.

**To insure accurate results,** the calipers must always be held against the piece being measured in such a manner that the dimension desired will be a line which is the *shortest* distance between the points of the calipers. For example, to find the diameter of a cylinder, the calipers should be held in a plane perpendicular to the axis of the cylinder, and then adjusted until its points will just pass freely over the cylinder. To read the distance between the points of outside calipers, place one of the

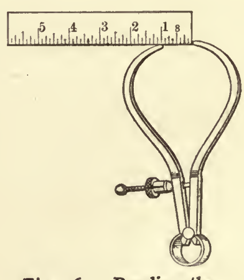


**Fig. 36. — Reading the Outside Calipers.**

points against the end of the rule and the other against the face, as shown in Fig. 36. To read the distance between the points of the inside calipers, place the end of the rule and one point of the calipers against a flat surface, as shown in Fig. 37.

**The dividers** (see Fig. 38) can often be used to determine dimensions with a greater degree of accuracy than is possible with the rule. To make a measurement with the dividers, their points are adjusted to fit the limits of the distance to be measured, and the points of the dividers are then applied to the *steel* rule, as shown in Fig. 26, page 25.

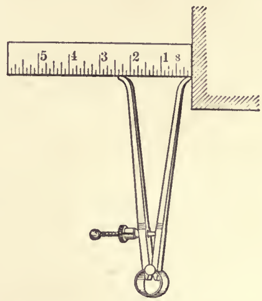


Fig. 37. — Reading the Inside Calipers.

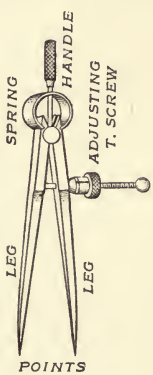



Fig. 38. — Ordinary Machinist's Dividers.

**Measurements that must be made extremely accurate** cannot always be obtained satisfactorily with either the measuring instruments or by the methods of making measurements as described above.

To measure accurately in hundredths, thousandths, etc., of an inch, special instruments are used, the most common of which is the **Micrometer;** a discussion of this instrument, however, is beyond the scope of this work.

**30. Blotter, Penwiper and Instrument Rag.** An ordinary **blotter** is often useful to the beginner to remove the *top* of a blot globule, but should never be used to blot the lines of the drawing. This dims the lines and tends to smear the work.

A small **linen rag** should be kept handy for cleaning the ink off the pens.

The **instrument rag** should be soft and free from lint. It is used in keeping instruments clean, but especially in removing dust and dirt from the triangles and from the T-square blade. If these instruments are not perfectly clean, they quickly soil the drawing in sliding over the surface. This rag should *not* be used to clean the ink off the pens.

# CHAPTER II

## LETTERS, NUMERALS, AND LETTERING

31. **Introductory.** Good lettering and dimensioning on working drawings is of prime importance and cannot be too strongly urged. A drawing may be well made and correct in all its details, but if the lettering be poorly done, the general appearance will be unsatisfactory and the value questionable. In most drawings the appearance is quite important, and in all it is desirable to secure the most pleasing effect possible. This does not mean that the lettering should be elaborate, or an effort made to secure artistic effects. There is no demand for such lettering on *working* drawings, but a style which is neat, well-appearing, easily read and easily made is required. The inclined Gothic alphabet, being free from unnecessary ornamental and superfluous features, fulfills all the requirements of lettering on engineering drawings and has been very generally adopted in practice.

The ability to do good lettering with this style of alphabet depends only upon a degree of manual skill that any beginner can acquire by *intelligent* practice combined with *careful* observation of the characteristics of the alphabet.

32. **The Study of Lettering.** Most beginners look upon freehand lettering as a difficult but purely *mechanical* process. This is a serious mistake, and as a result progress is retarded and the work is uninteresting.

The letters and numerals in the alphabets have been *evolved* through years of use, and unless the beginner studies their form and proportions and endeavors to reproduce them, he cannot hope to acquire the art of lettering. The outline and characteristics of *each letter and numeral must be carefully studied and fixed* in the mind. The beginner is greatly aided in learning the characteristics of the letters of the alphabet by so grouping

them that comparisons can be made as to their points of similarity and difference; for example, groups could be made up as follows:

(*a*) *Letters composed entirely of straight lines.*
(*b*) *Letters composed wholly or partly of curved lines.*
(*c*) *Letters of the same width.*
(*d*) *Letters of the same height.*
(*e*) *Letters of similar outline.*

Thus, *I*, *L*, *E*, and *F* form a group of letters all of which begin with a line of "standard slope" (i.e., a line which has the same slope as the alphabet) and have parallel branches. The "bar" in both the *E* and *F* is exactly midway between the top and bottom of the letter, and its length is the same as its distance from the top or bottom; it is more than one-half but less than three-fourths as long as the upper width of the letter. The top width of the *E* equals that of the *F*, but the lower width of the *E* is five units while the lower width of the *L* is only four and one-half units. The fact that *E* is wider at the bottom than at the top suggests another group, composed of *E*, *B*, *K*, *Z*, and *X*, all of which are wider at the bottom than at the top. The reason for making these letters wider at the bottom is to give an appearance of stability. If these letters are made the same width throughout, they appear top-heavy. The *I*, *H*, *N*, and *M* have parallel sides which have the slope of the alphabet and would *not* appear well if made wider at the bottom. There is a difference in the slope of similar sides of *V* and *W*, and neither contains a line of standard slope. Other groups that should be studied are *O*, *Q*, *C*, and *G; P*, *R*, and *B; U* and *J; a*, *d*, *q*, and so on. This method of studying the alphabet and comparing letters will develop a fine *sense of proportion* and will also train the eye to *see form* properly, both of which are essential not only in lettering but also in sketching and drawing.

*Ultimately* the draftsman does not rely upon his memory for spaces, widths, heights, and proportions of the letters, but this *sense of proportion* enables the eye to judge the accuracy of the construction, the alignment of the letters, and the proper spacing *while the letters are being formed,* and lettering free-hand

is then no more difficult or tiresome than writing. Progress at the start will depend in a large measure upon the beginner's ability to criticize *his own* work and his willingness to correct all errors as soon as they are detected.

If patience and thought are exercised *from the start* the beginner will soon acquire the ability to do *good lettering* and it will then take no longer to make well-formed letters than poorly-made ones.

**To make a critical study of lettering, note as follows:**

(*a*) *Whether the tops and bottoms of the letters appear to be in line.*

(*b*) *If the proper spacing has been maintained between letters, words, sentences, and lines of lettering.*

(*c*) *If each letter has the proper slope.*

(*d*) *If each letter has the proper proportion of height to width.*

(*e*) *If the different lines composing each letter are the proper relative length and shape.*

It will be observed that the first thing to notice is whether the letters *appear* to be in line. In lettering, *mathematical* measurements will not always produce satisfactory results. On account of the sharp angles of such letters as *A*, *V*, *W*, and the curves of *O*, *C*, *Q*, *G*, they *appear* shorter than such letters as *H*, *N*, *E*, *M*, when made exactly the *same* height, and for this reason it is best to make them extend *very slightly* beyond the guide line in order to have them *appear* the same height. Also it often happens that a deviation from the standard width of letters is an advantage. Thus, an *L* followed by an *A* can be made narrower than if it were followed by an *N* or an *H*, or than if it were at the end of a word.

**33. Slope of Letters.** The vertical and the inclined alphabets are used in practice, but the inclined letters are usually preferred, since it is more difficult to make vertical letters appear uniformly regular. This is because the eye naturally compares the free-hand vertical lines of the letters with the mechanically made vertical lines of the drawing and consequently any slight imperfection is noticeable. Also, to be correct and appear well,

the vertical letters must always be *exactly* vertical or at right angles with the bottom guide line, while with the inclined letters the *exact* angle of inclination is not of great importance as long as uniformity of inclination is maintained, and the draftsman may give his letters the slope that is easiest for him to maintain. While, as has been said, inclined lettering is usually preferred, there are many instances, however, where vertical lettering, *if well done*, is preferable.

**The slope to be used in this work is 2 to 1,** which corresponds to an angle of about $63\frac{1}{2}°$. **To obtain a slope of two to one,** lay off any convenient distance along a straight line and twice this distance on a second straight line erected at the right-hand end of and at a right angle with the first line. A third line joining the extreme outer ends of these two lines has the slope desired. The beginner should notice that the lines of the inclined alphabet which are drawn with a slope of two to one (that is, standard slope lines) *correspond* to the vertical lines of the vertical alphabet.

**34. General Description of Model Letters.** The illustrations in § 38, page 44, and § 41, page 51, show the correct proportions of the letter, and the written matter calls attention to certain important points to be kept in mind when forming the letter. To help in this work, "guide lines," "center lines," "dimension lines," and "direction arrows" are made use of.

The **stem** of a letter is any portion of the outline which is straight and has the slope of the alphabet, this term being most commonly used in connection with the description of the small letters of the alphabet.

The **top** and **bottom guide lines** limit the height of the letters and are an aid in keeping them in line. The **side guide lines** have the same slant as the alphabet. They limit the width of the letters, and aid in maintaining the proper slope.

**Center lines** are used on letters having a form which can be divided more or less symmetrically by such lines; they also determine the points where certain letters are tangent to the guide lines. Center lines that are parallel to the top and bottom guide lines are called **horizontal center lines**; those having

the same slope as the alphabet are called **standard slope center lines,** and those having a slope other than that of the alphabet are called **sloping center lines.** A letter is built around a center line in somewhat the same manner as a sketch would be built about its center lines. (See page 137, § 97.)

*Guide lines and center lines for lettering should be drawn continuous or unbroken throughout their length, but very light, as they are erased as soon as the lettering is completed.*

**The dimensions shown on the model letters** will enable the beginner to study the relative ratio of width to height of letters and the relative proportions of the different lines forming the individual letters. (See page 45, § 38.)

**The numbers appearing with the letter-dimension lines** on the model indicate the units of space between the arrowheads. This unit is the *length* of the side of a small square of the section paper, and on the paper used for this work the length of a side is $\frac{1}{8}$ inch, so that 3 would indicate the length of three of the small squares, or $\frac{3}{8}$ inch; 5 would indicate five squares, or $\frac{5}{8}$ inch, etc. (See page 58, § 44.)

When the term **standard slope** is used in describing the model letters and numerals, it refers to a line of the letter having the same slope as the alphabet, which throughout this work is the slope corresponding to 2 to 1 or approximately to $63\frac{1}{2}°$.

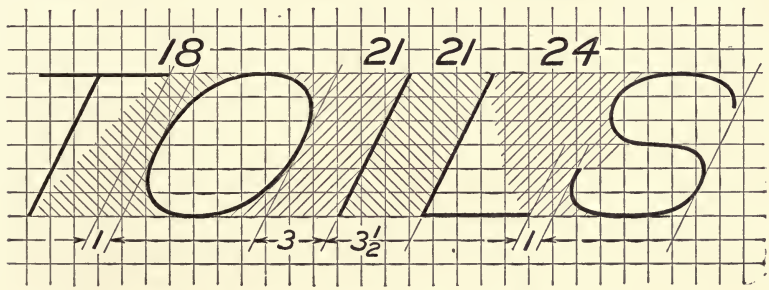
**Direction arrows on the model letters** point in the direction the pencil should move in making each stroke. (See page 64.)

**The number written across the direction arrow** indicates the order in which the strokes should be made. (See page 64.)

This **system of strokes** should be closely followed by the beginner, as it points the way to easy and rapid lettering. Later on, when more familiar with the characteristics of the letters and when greater skill has been gained in handling the pencil or pen, the number of strokes may be reduced in order to acquire speed, but *the first stroke should be the one which determines the spacing between the letter being formed and the preceding letter,* the order of the strokes should follow the easiest method of securing the desired outline, and the general direction of strokes should be either down (toward the body) or toward the right *when lettering free-hand.*

**35. Spacing.** It is fully as important to place letters the proper distance from one another as it is to form them correctly. Each letter in a word may be perfectly formed, but if all the letters have not been properly spaced the lettering will not *appear* uniform. The eye judges the space between letters *as an area* rather than a *linear* distance, and if separated by exactly equal distances, the areas outlined between adjacent letters will not be *uniform* in different combinations of straight and curved letters. Thus, a combination of letters with standard slope sides falling adjacent, as *MINE*, would call for wide spacing as compared with such a combination as *COG;* while the adjacent sides of the letters of the word *AT* would have to "overhang" so that the spacing may appear uniform. Another extreme combination can be formed of half-open-side letters, as *FTY*. If it were possible to make these combinations fall in groups as illustrated, it would not be difficult to state rules for spacing; but with twenty-six different letters a great many different combinations are possible, and *the problem of spacing cannot be covered by a single rule*. Rules that will prove valuable to the beginner are given below but the appearance of the finished work, in so far as spacing is concerned, will in the end depend upon the judgment exercised in maintaining the *appearance of equal areas* between the letters.

**The distance between letters** is measured in a line parallel to the top or bottom guide-line and between the side-guide-lines which fall adjacent. Based on this idea the "Key to Spacing" (see page 43) has been compiled and the distances given below




have been carefully found by laying out on a large scale various side-line combinations (see above figure) and determining a spac-

ing that, in view of the *area* enclosed, gives the best spacing for such a combination. In the illustration the shaded portion represents the "area" to be considered in determining the spacing which is shown between the side-guide-lines.

**By element of adjacency** is meant that side-line of a letter which is nearest to the adjacent letter under consideration.

**(A) Spacing for various line combinations in Capital Letters** presented in three different forms as follows:

(I) *Combinations classified by space units.*

(II) *Combinations classified by side-line grouping.*

(III) *Side-line combinations and corresponding spacing shown by chart.*

In learning to space method (I) should be the guide but as a further aid in certain combinations method (II) or (III) can be used but "spacing" has not been properly grasped until the judgment alone is relied on for satisfactory results.

## (I) COMBINATIONS CLASSIFIED BY SPACE UNITS

A standard slope side followed by a standard slope side requires **three and one half spaces,** thus, $N_{3\frac{1}{2}}I_{3\frac{1}{2}}N_{3\frac{1}{2}}E$.

A standard slope side adjacent to a curve side requires **three spaces,** thus, $C_3H_3O_3I_3C_3E$.

A combination side followed by a standard slope or a curve side, also two curve sides adjacent, require **two and one half spaces,** thus, $P^{2\frac{1}{2}}R_{2\frac{1}{2}}I_{2\frac{1}{2}}S_{2\frac{1}{2}}M_{2\frac{1}{2}}S$.

A standard slope side followed by any one of the letters, *Z*, *V*, *W*, *A*, *X*, also any one of the letters *Z*, *V*, *K*, *W*, *A*, *X*, followed by *V* or *W* or by a standard slope side, require **two spaces,** thus, $M_2A_2K_2E$.

A standard slope side followed by *Y* or *T*; — a curve or combination side followed by any one of the letters *Z*, *V*, *W*, *A*, *X*; — the letters *K*, *X*, or *Z* followed by a curve side; — any one of the letters *L*, *Y*, *F*, or *T* followed by a standard slope side require **one and one half spaces,** thus, $F^{1\frac{1}{2}}L_{1\frac{1}{2}}E^{1\frac{1}{2}}W$.

All other combinations require **one space,** thus $T^1O^1Y^1S$, *except* *T*, *Y* and *F* when followed by *A*, *X* or *Z*; also the *L* or *A* when followed by *T* or *Y*, which require **zero spacing,** thus $L_0A_0Y$ **or** $A_0T$, etc.

## (II) COMBINATIONS CLASSIFIED BY SIDE-LINE GROUPING

Letters with *a standard slope side* [*H*, *I*, *M*, *N*] when followed
- (1) by *a standard slope side* [*B*, *D*, *E*, *F*, *H*, *I*, *K*, *L*, *M*, *N*, *P*, *R*, *U*] require $3\frac{1}{2}$ spaces.
- (2) by *a curved side* [*C*, *O*, *G*, *Q*, *S*] require 3 spaces.
- (3) by *a* ⊥ or *a 45° side* [*V*, *W-A*, *X*, *Z*] require 2 spaces.
- (4) by *a half-open side* [*T*, *Y*, *J*] require $1\frac{1}{2}$ spaces.

Letters with *a curved side* [*C*, *O*, *G*, *Q-J*, *U-B*, *D*] when followed
- (1) by *a standard slope side* [*B*, *D*, *E*, *F*, *H*, *I*, *K*, *L*, *M*, *N*, *P*, *R*, *U*] require 3 spaces.
- (2) by *a curved side* [*C*, *O*, *G*, *Q*, *S*] require $2\frac{1}{2}$ spaces.
- (3) by *a* ⊥ or *a 45° side* [*V*, *W-A*, *X*, *Z*] require $1\frac{1}{2}$ spaces.
- (4) by *a half-open side* [*T*, *Y*, *J*] require 1 space.

Letters with *a combination side* [*R*, *E*, *P*, *S*] when followed
- (1) by *a standard slope side* [*B*, *D*, *E*, *F*, *H*, *I*, *K*, *L*, *M*, *N*, *P*, *R*, *U*] or by *a curved side* [*C*, *O*, *G*, *Q*, *S*] require $2\frac{1}{2}$ spaces.
- (2) by *a* ⊥ or *a 45° side* [*V*, *W-A*, *X*, *Z*] require $1\frac{1}{2}$ spaces.
- (3) by *a half-open side* [*T*, *Y*, *J*] require 1 space.

Letters with *a* ⊥ or *a 45°* or *a full open side* [*V*, *W-A-K*, *X*, *Z*] when followed
- (1) by *a standard slope side* [*B*, *D*, *E*, *F*, *H*, *I*, *K*, *L*, *M*, *N*, *P*, *R*, *U*] require 2 spaces.
- (2) by *a* ⊥ *side* [*V*, *W*] require 2 spaces.
- (3) by *a curved side* [*C*, *O*, *G*, *Q*, *S*] require $1\frac{1}{2}$ spaces.
- (4) by *a 45° side* [*A*, *X*, *Z*] require 1 space.
- (5) by *a half-open side* [*T*, *Y-J*] require 1 space or 0 space.

Letters with *a half-open side* [*L-F*, *T*, *Y*] when followed
- (1) by *a standard slope side* [*B*, *D*, *E*, *F*, *H*, *I*, *K*, *L*, *M*, *N*, *P*, *R*, *U*] require $1\frac{1}{2}$ spaces.
- (2) by *a* ⊥ or *a curved side* [*V*, *W-C*, *O*, *G*, *Q*, *S*] require 1 space.
- (3) by *a 45°* or *a half-open side* [*A*, *X*, *Z-T*, *Y-J*] require 1 space or 0 space.

## (III) SIDE-LINE COMBINATIONS AND CORRESPONDING SPACING SHOWN BY CHART

The chart given on page 43 is used in the following manner. Assume as an example that the letters of the word *COLLEGE* are to be spaced. First, in the left-hand column locate the letter *C*, then move horizontally and to the right until the column containing the capital *O* at the top is located, and it is seen that the side-line classification is *curved side* followed by *curved side*, and, reading directly under the *O* and in line with the *C*, the spacing is $2\frac{1}{2}$ units. Similarly the combination of the letters *O* and *L* is a *curved side* followed by *standard slope line*, and in a horizontal line with the *O* and directly under the *L* the chart shows the spacing as 3 units. Studying out all the combinations, the spacing is as follows: $C_{2\frac{1}{2}}O_{3}L_{1\frac{1}{2}}L_{1\frac{1}{2}}E_{2\frac{1}{2}}G_{3}E$.

(B) **Spacing for Numerals.** The "standard" spacing for numerals is **two and one half** space units but in such combinations as involve the *left hand side* of the *3*, the *4* and the *7* this distance should be slightly reduced and in such combinations as involve the *1* or the *right hand side* of the *4* (measured from the stem) this standard spacing is slightly increased.

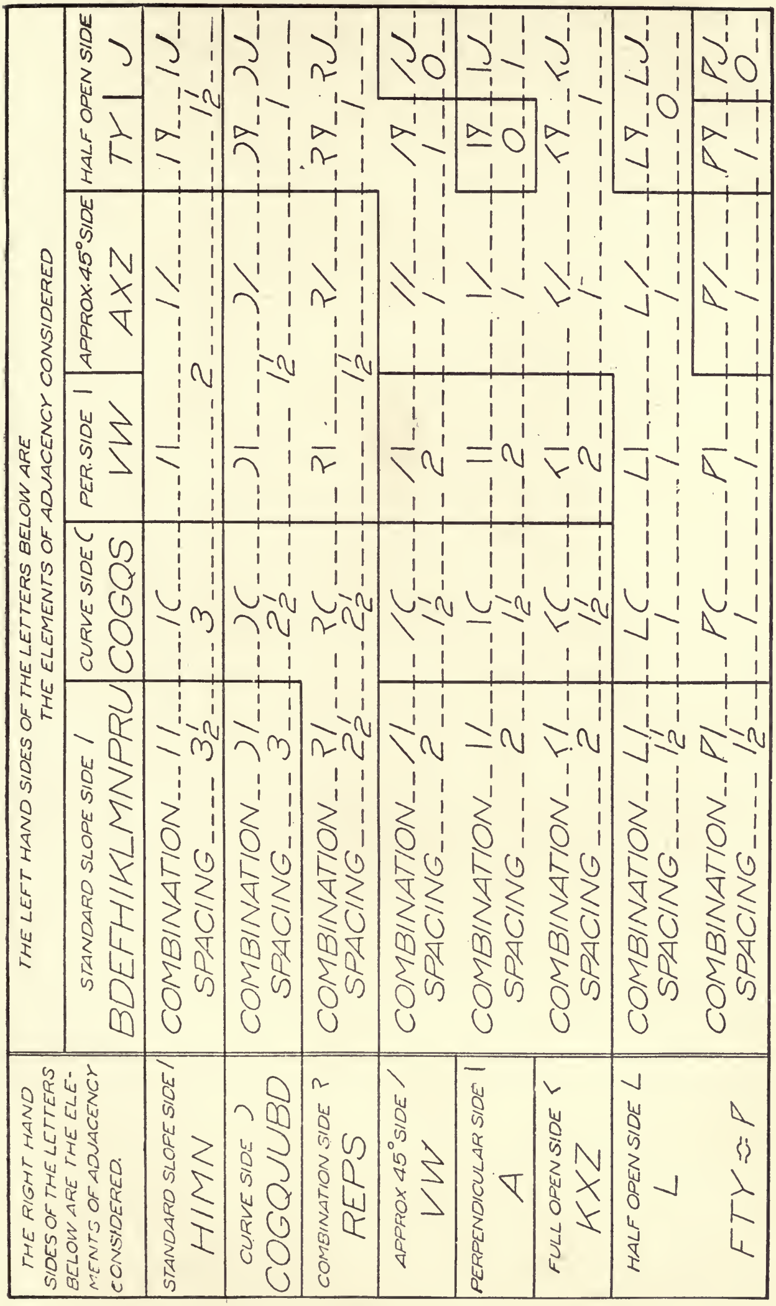
(C) **Spacing for Capital Letters in combination with Small Letters and for Small Letters.** Small letters are about *two thirds* the height of capital letters and numerals of the same alphabet and hence small letters require **a spacing of about two thirds** that given for a similar side-line combination of the capital letters.

(D.) **Spacing between words and between sentences.** Care must be taken to have the proper space between words and a *greater* space between sentences, otherwise the lettering is not so easily read, even though the individual letters are correctly formed and spaced.

The **spacing between words** should be slightly more than twice the average space separating letters.

The **spacing between sentences** should be about twice that separating words.

**Where punctuation marks are necessary extra space is allowed.** The punctuation mark is placed nearer the word which precedes




Spacing Chart for Slant Gothic Letters.

it than the one which follows. The comma and the semicolon each require a space between the mark and the following word equal to the space between words.

**36. Systematic Method of Lettering.** Before starting the outline of a letter, draw very lightly all guide lines and center lines that will be an aid in its construction.

**When forming a letter, make all lines very light at first,** and, with the outline correct, retrace, making the lines of *medium* weight.

All construction lines are then erased, and the correct outline, which will be made dim by the erasing, is again retraced and made clear cut and of the desired weight. In retracing, the strokes should always be made in the direction and order indicated by the arrows on the model letters. See § 38, this page.

For full instructions as to how to make free-hand lines see page 134, § 95, also page 136, § 96.

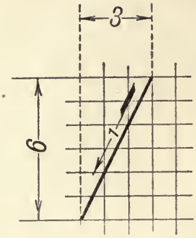
**37. The Size and the Lettering of Letter Sheets.** Exercises in free-hand lettering will be done on small sheets of standard letter size (8″ × 10½″), heavy weight, cross-section paper ruled on one side (see page 5, § 4), and punched for standard #10 Manila cover.

The order in which free-hand lettering sheets are executed will be **indicated by capital letters,** beginning with *A* and continuing as far as necessary. For full information as to the general system to be followed, see Appendix, page 175.

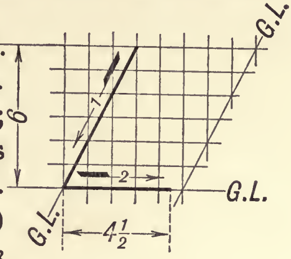
## SET OF FREE-HAND LETTERING EXERCISES.

**38. Outline and Characteristics of Capital (or Upper-case) Letters Composed of Straight Lines Only.** Over half of the capital letters of the inclined Gothic alphabet are composed entirely of straight lines, and several of these straight-line letters are very similar. In the following paragraphs the characteristics of straight-line capital letters are pointed out.

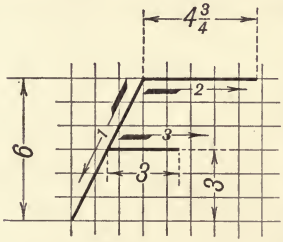
In order to fully understand the subject matter of this paragraph, carefully read § 34, page 37.



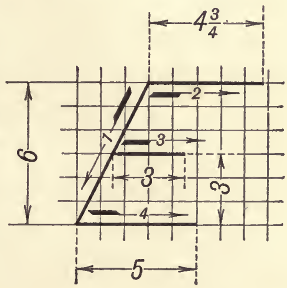

**Capital I.** 1 stroke of standard slope. The width of the letter is the width of the line and should not differ from that of all other standard slope lines. Do *not* dot the capital *I*.



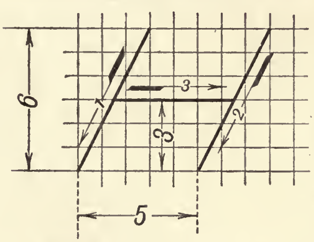

**Capital L.** 2 strokes. #1 is standard slope; #2 is drawn horizontal. Note that #2 is shorter than the corresponding line of *E*. (See this page.)



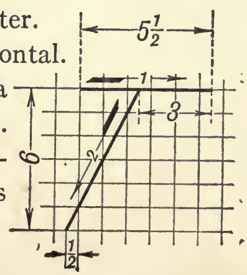

**Capital F.** 3 strokes. #1 is standard slope; #2 is the same as #2 of *E* (see this page); #3 starts from the middle of #1 and is drawn horizontal and should *never* be drawn below the middle of the letter or be as long as #2.




**Capital E.** 4 strokes. #1 is standard slope; #2 the same as #2 of *F*; (see this page); #3 the same as #3 of *F*. #4 is parallel to #2 but is slightly longer. #2 is also longer than the corresponding line of the *L*. (See this page.) Note that #2 and #4 are each shorter than the corresponding lines of *Z* (see page 47).

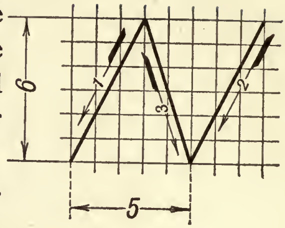


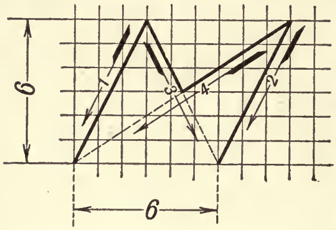

**Capital H.** 3 strokes. #1 and #2 are each standard slope. Note that these two parallel lines would do for the *N*. (See page 46.) #3 starts at the middle of #1, is drawn horizontal and should *never* be drawn below the middle of the letter.




**Capital T.** 2 strokes. #1 is drawn horizontal. #2 is standard slope and is drawn from a point slightly to the left of the center of #1. Note that #1 is longer than the corresponding lines of *E* (see this page), *F* (see this page), and *Z* (see page 47).

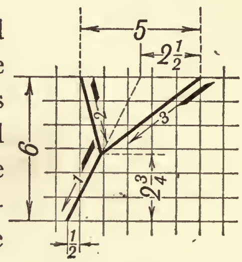
**Capital N.** 3 strokes. #1 and #2 are each standard slope, as in the *H*. (See page 45.) Stroke #3 must meet #1 and #2 *exactly* at the extremes of the proper ends.

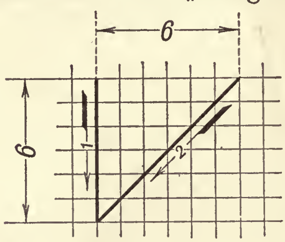


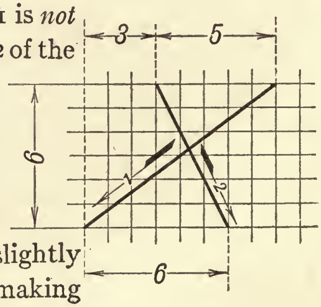

**Capital M.** 4 strokes. #1 and #2 are each standard slope, and are drawn a distance apart equal to the height of the letter. #3 and #4 are first drawn very lightly, the lower segments of which are erased in the finished letter. The angle between #3 and #4 must not be too acute or the letter will appear to be compressed, or if too large the letter will appear "widened." The *M* is *not* the same as the *W* inverted. (See page 47.)

**Capital Y.** 3 strokes. #1 is a standard slope line drawn through the center of the letter but slightly less than the lower half is used in the completed letter. Strokes #2 and #3 each start from points on the top guide line which are equidistant from the intersection of #1 (extended) and the top guide line and meet #1 slightly *below* the center.



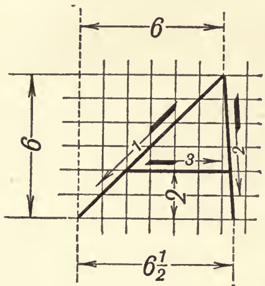




**Capital V.** 2 strokes. Note especially that #1 is vertical and #2 makes 45° with it; also the letter is wider at the top than any straight line letter excepting the *M* (see this page) and the *W*. (See page 47.) Also #1 is *not* parallel to #2 of the *A* (see page 47), and no line has the standard slope. The capital and the small *v* are similar (see page 67).



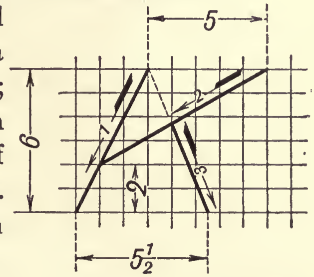

**Capital X.** 2 strokes. #2 has a slope of 2 to 1 and should cross #1 at a point on the sloping center line slightly *above* the center of the letter, thus making

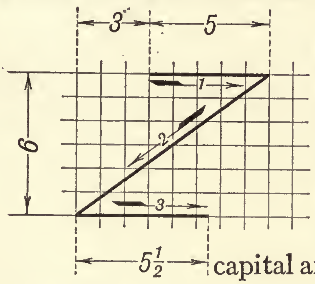
the letter wider at the bottom than at the top, otherwise it appears top-heavy. The capital and the small *x* are similar. See page 67.




**Capital A.** 3 strokes. #1 makes 45° with top and bottom guide lines. #2 is drawn from the extreme top of #1 to the base of the right guide line and is not a vertical line, thus #2 is not parallel to #1 of the *V*. (See page 46.) #3 is horizontal and one-third the distance from the bottom to the top of the letter, and thus is always below the center of the letter. Note that no lines of this letter have the standard slope.

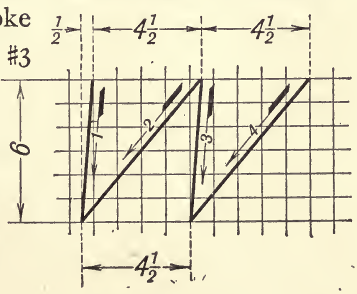
**Capital K.** 3 strokes. #1 is standard slope. #2 is drawn to meet #1 at a point one-third the height of letter; i.e., *below* center of letter. #3 is drawn very lightly, the upper segment of which is erased in the finished letter. Note that the letter has a greater width at the bottom than at the top.




**Capital Z.** 3 strokes. Draw very lightly two sloping side guide lines. #1 is horizontal and starts from the left guide line. #3 is parallel to #1, but slightly longer. Note that #1 and #3 are longer than the corresponding lines of the *E*. (See page 45.) The capital and the small *z* are similar. See page 67.

**Capital W.** 4 strokes. No stroke has the standard slope. #1 and #3 each incline slightly to the right and are parallel; also #2 and #4 are parallel. Note that the letter *W* inverted would *not* be the same as the *M*. (See page 46.) The capital and the small *w* are similar. See page 67.



**39. Sheet A.** The purpose of this sheet is to teach the form and characteristics of the capital letters of the inclined Gothic alphabet, which are constructed entirely of straight lines, also to give practice in making these letters.

Before starting this sheet read and be prepared for examination on the following paragraphs:

The Pencil Pointer, see page 14, § 13, — Lead Pencil, see page 14, § 14, — Erasers and Erasures, see page 16, § 15, — The Free-hand Pencil Line, see page 134, § 95, — Introductory, see page 34, § 31, — the Study of Lettering, see page 34, § 32, — The Spacing of Letters, Words and Sentences, see page 39, § 35, and for information on the general system to be followed see page 175, Appendix A.

*Exercises on Sheet A.* These exercises consist of capital letters of the simplest form. Before beginning the construction of any letter, study carefully the illustration of that letter in the model alphabet (see page 44, § 38) and read all descriptive matter relating to it. Also see § 37, page 44.

**Do not use a straightedge in doing any part of a free-hand exercise as this will seriously impair the value of this work.** Lines so made are easily detected and as a result the sheet will not be accepted.

*Specific Instructions for Executing Sheet A.* Tack down the sheet (see page 8, § 9), stamp in title form (see page 138, § 98) and the wording in the title form is next to be neatly *written in ink.*

The title of sheet *A* is *CAPITAL LETTERS.*

Proceed with the letters systematically, and complete the sheet as shown in Fig. 39, but omit arrows. Practice making a free-hand pencil line on scrap paper before starting sheet *A*. This practice can best be accomplished by making a *free-hand* copy of some simple drawing, such as Fig. 97 on page 140, continuing to practice until a " clear cut " line can be made (see page 78, § 54). Also the beginner should at this time learn to sharpen a pencil with care (see page 15, § 14) and to use an eraser to the best advantage (see page 16, § 15).

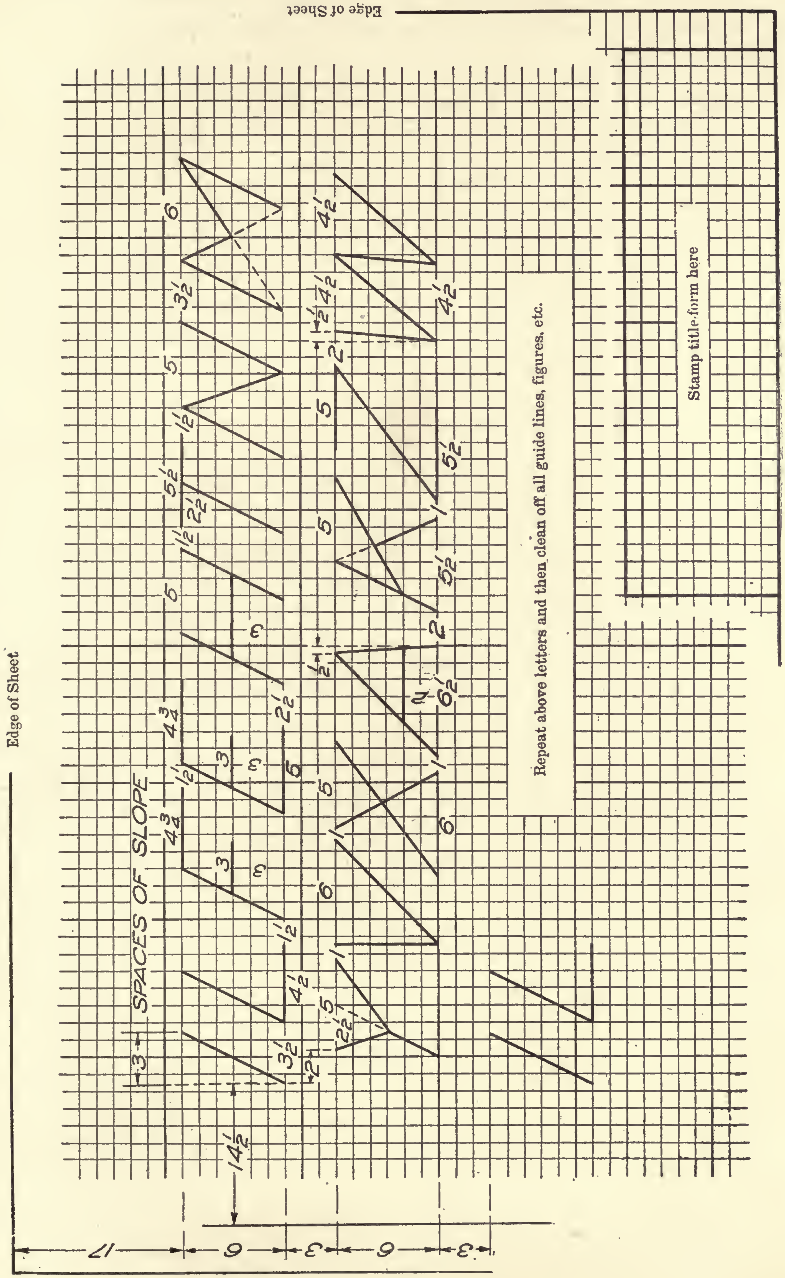



Fig. 39. Layout for Sheet A.

The first letter to be drawn is the capital *I*, and the bottom of this letter is to be located 23 spaces from the top edge and $14\frac{1}{2}$ spaces from the first *heavy* vertical cross-section line on the left side of the sheet.

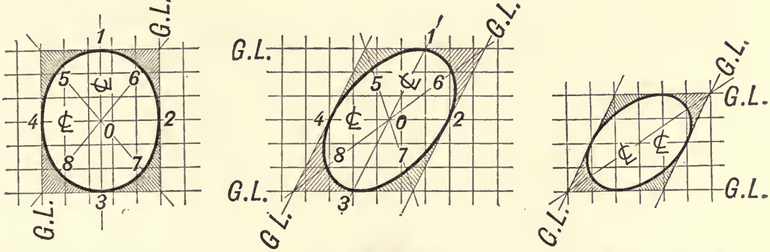
Having satisfactorily completed the outline of all letters, clean the sheet (see page 17, § 15), and **go over all lines, making them clear cut and finished.** See page 78, § 54.

**Thoroughly examine the work** to see that nothing has been omitted; *correct any errors*, and, after the sheet has been inspected, write the Date Finished and the Total Actual Hours in the title form, and submit the sheet for final approval.

**40. The Sloping Ellipse.** A large number of capitals, small letters, and numerals of the inclined Gothic alphabet have an outline which is partly or entirely oval. This oval approaches more nearly the "sloping ellipse" than any other curve, and the beginner should understand the construction of such a curve before attempting to form the curved letters. The exact shape of any ellipse is determined by the ratio between its long and short axes. Fig. 40(a) shows an ellipse with its long axis vertical and having a ratio of width to height of 5 to 6, this ratio being common to many letters. This ellipse is tangent to the guide lines at the points 1, 2, 3, 4, and is symmetrical about both the long axis and the short one. Therefore the diagonals 5 to 7 and 6 to 8 are of equal length, also the four shaded areas outside the ellipse are equal and have the same shape.

A "sloping ellipse" is shown in Fig. 40(b). In this construction the long axis has the *slope of the alphabet* (2 to 1), but the short axis remains horizontal. When this curve is drawn in a parallelogram and is tangent at the extremities of the axes, the lines 1 to 3 and 2 to 4 do *not* divide the ellipse symmetrically. The shaded areas are therefore not of the same shape, but those diametrically opposite are the reverse of each other. That is, in the sloping ellipse the upper left-hand quadrant of the curve is the same as the lower right-hand quadrant but reversed in relative position, and similarly the upper right-hand quadrant is the same as the lower left-hand quadrant but reversed in relative position. The "sloping ellipse" is therefore

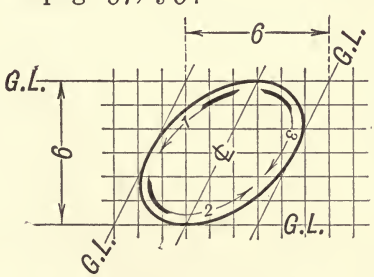
not of the true ellipse construction but is an ellipse so modified that its major axis has the slope of the alphabet, and the curve is tangent to the limiting parallelogram at the extremities of the axes. In certain portions of the outlines of some of the capital




(a) Vertical. (b) Medium Slope. (c) Extreme Slope.
Fig. 40.—Ellipses.

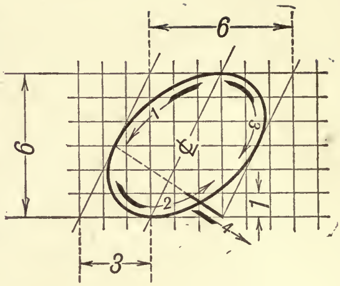
letters and in the case of certain small letters a much better shaped letter is obtained if the slope of the ellipse is made greater than the standard slope as shown in Fig. 40(c). Approximately the same effect can be obtained in some of the capital letters by the use of circular arcs as shown in *D*, *U*, *J*, *P*, *B*, and *R*, pages 52 and 53. The use of the small ellipse [see Fig. 40(c)] in small letters is shown on pages 63, 64 and 65.

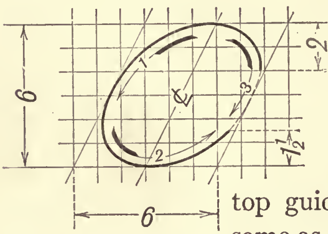
**41. Outline and Characteristics of Capital (or Upper-case) Letters Composed Wholly or Partly of Curved Lines.** For general discussion of guide lines, center lines, dimension lines, and arrows as used in connection with lettering and numbering, see page 37, § 34.




**Capital O.** 3 strokes. Draw two side-guide-lines such that their distance apart is equal to the width of the letter. Bisect the parallelogram by two center lines, as shown, and locate the points of tangency of the guide lines and ellipse. Draw in the sloping ellipse in the order of the strokes. For full description and construction of the "sloping ellipse" see page 50, § 40. The capital *Q* and the small *o* are similar. See page 63.

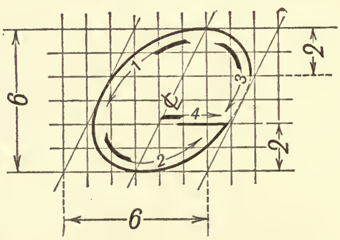
**Capital Q.** 4 strokes. Three strokes, as for *O*. (See page 51.) #4 is drawn very lightly from the left-hand point of tangency to the intersection of the right-hand and bottom guide lines. Erase about two-thirds of the left-hand portion of this line and retrace the remaining portion medium weight.

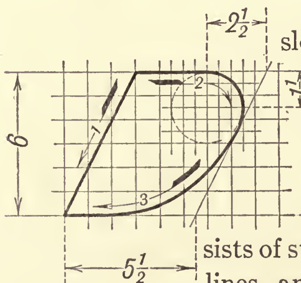



**Capital C.** 3 strokes. Proceed as with *O* (see page 51), excepting that #2 and #3 are shortened. The opening in the ellipse is slightly greater than one-third the height of letter and *nearer the bottom* than the top guide line but the letter width is the same as the *O*. The capital *C* and the small *c* are similar. See page 64.

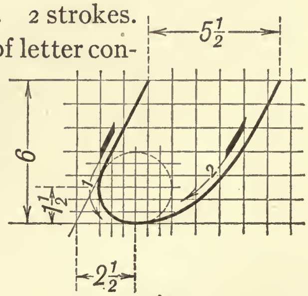
**Capital G.** 4 strokes. #1 and #3 are the same as for *C*. (See this page.) #2 is longer than #2 in *C* and extends up one-third the height of letter. #4 is horizontal and extends one-third across the letter.

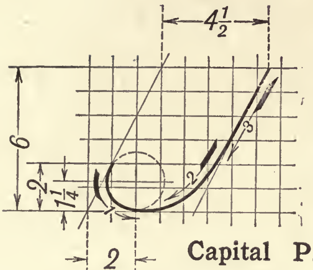


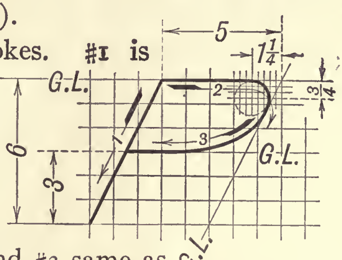

**Capital D.** 3 strokes. #1 is standard slope. The right-hand half of the letter is practically the same as the right half of *O*. (See page 51.) The *D* is slightly narrower than the *O*.

**Capital U.** 2 strokes. Upper half of letter consists of standard slope lines, and lower half is practically the same as lower half of *O*. (See page 51.) The *U* is slightly narrower than the *O*.



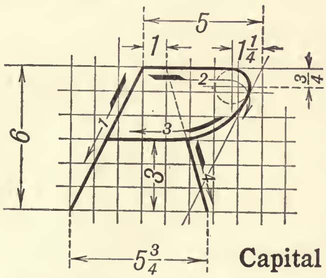


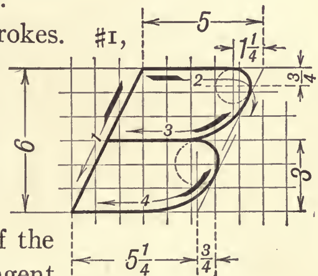
**Capital J.** 3 strokes. #3 is two-thirds the upper portion of a standard slope line. Note that *J* is relatively narrow. The lower portion of the letter is part of a small modified sloping ellipse. See page 50, § 40, Fig. 40 (c).




**Capital P.** 3 strokes. #1 is standard slope. #2 is partly horizontal and partly small modified sloping ellipse. See page 51, § 40. Note that portions of #2 and #3 are parallel.

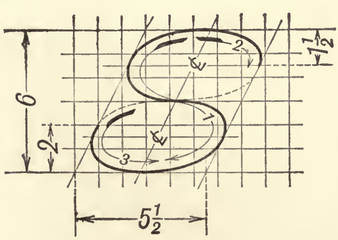
**Capital R.** 4 strokes. #1, #2, and #3 same as #1, #2, and #3 for *P*. (See this page.) #4 is drawn so as to make the *R* wider at the bottom than at the top and should be drawn in such a direction that it would intersect #1 (extended) slightly above the top guide line.



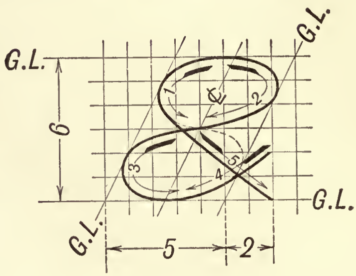


**Capital B.** 4 strokes. #1, #2, and part of #3 same as #1, #2, and #3 for *P*. (See this page.) The lower half (or lobe) of *B* is of the same form but slightly wider than the upper lobe.

**Capital S.** 3 strokes. Draw all guide and center lines. The outline of the letter consists of *portions* of two tangent modified ellipses, exactly the same size and slope but in reversed relative position. #1 is the left half of upper ellipse and the right half of lower ellipse. #2 is drawn from the top point of tangency, #3 to the lower point of tangency. Locate accurately the seven points of tangency before "roughing in" ellipses and see that the outline



is tangent at the center of the letter but is *not* drawn below the horizontal center line at the middle of the letter. The capital and the small *s* are similar. See page 66.




**Abbreviation &.** 5 strokes. #1, #2, and #3 are almost the same as for the numeral *8*. (See page 59.) Note especially where #4 and #5 begin and end.

**42. Sheet B.** The purpose of this sheet is to teach the form and characteristics of the capital letters of the inclined Gothic alphabet, which are constructed wholly or partially of curved lines, and to give practice in making these letters.

Having had the experience of making sheet *A*, again read paragraph 34, page 37, with reference to the Model letters.

For information on the general system to be followed see Appendix A, page 175.

*Exercises on Sheet B.* These exercises include all capital letters of the inclined Gothic alphabet not given on Sheet *A*.

Before attempting to form a letter, study carefully the illustration and description of that letter in the model alphabet. See page 51, § 41.

*Specific Instructions for Executing Sheet B.* Tack down the sheet, stamp in and fill out the title form. The wording in the title form is to be neatly *written in ink*.

The title of Sheet *B* is *CAPITAL LETTERS*.

Locate the letters on the sheet according to the space dimensions shown in Fig. 41. Proceed with the lettering systematically (see page 44, § 36) and complete, as shown in Fig. 41. Having satisfactorily completed the outline of all letters, clean the sheet and retrace all lines, making them clear cut and of the desired weight.

Carefully examine the work to see that nothing has been omitted; correct any errors, and, after the sheet has been thoroughly inspected, write in with ink the Date Finished

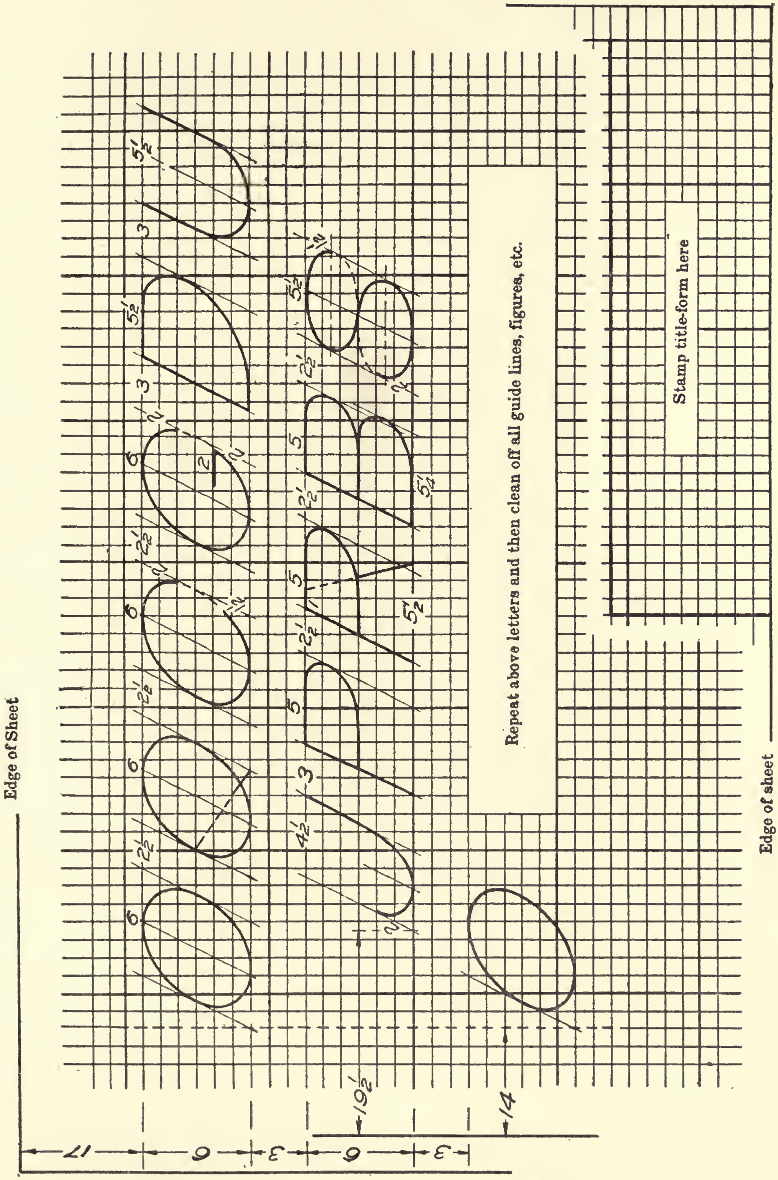



Fig. 41. — Layout for Sheet B.

and Total Actual Hours, and submit the sheet for final approval.

43. **Sheet C.** The purpose of this sheet is to teach the beginner to *correctly maintain* all relative proportions of letters and spacing in lettering of the size usually found on practical drawings.

The first alphabet at the top of the sheet is reduced to one-half size; this means that dimensions given on Sheet *A* (page 49, Fig. 39) and Sheet *B* (page 55, Fig. 41), including the spacing, are reduced one-half.

The second alphabet on Sheet *C* is reduced to one-third size, and the unit of space is one-third that given on Sheets *A* and *B*.

The lettering in the note at the bottom of Sheet *C* is only one space high, that is, it is *one-sixth* size, and the spacing between letters, words, and sentences must be reduced accordingly.

*Specific Instructions for Executing Sheet C.* Tack down the sheet, stamp in and fill out the title form.

The title of Sheet *C* is *REDUCED-SIZE LETTERING.*

Locate numbers and letters on sheet, as shown in Fig. 42.

When all lettering has been satisfactorily completed in pencil, clean the sheet and retrace all lines, making them the proper weight.

Every possible precaution should be taken to prevent soiling the sheet and to avoid the necessity of making changes. As this sheet is to be inked, any erasing which tends to injure the surface of the drawing makes satisfactory inking very difficult. This sheet must be finally approved in pencil *before* it is inked in.

Thoroughly examine the work to see that nothing has been omitted; correct any errors, and, after inspection and approval, the sheet is ready for inking. Before attempting to ink any work the beginner should practice inking on scrap paper. See page 136, § 96. Such preliminary practice accustoms the hand to the touch of the pen and avoids experiments on approved penciled sheets, which would most likely spoil them.

*Specific instructions for Inking Sheet C.* Tack down the approved penciled sheet on the drawing board and, before beginning to practice *inking* on scrap paper, read and prepare

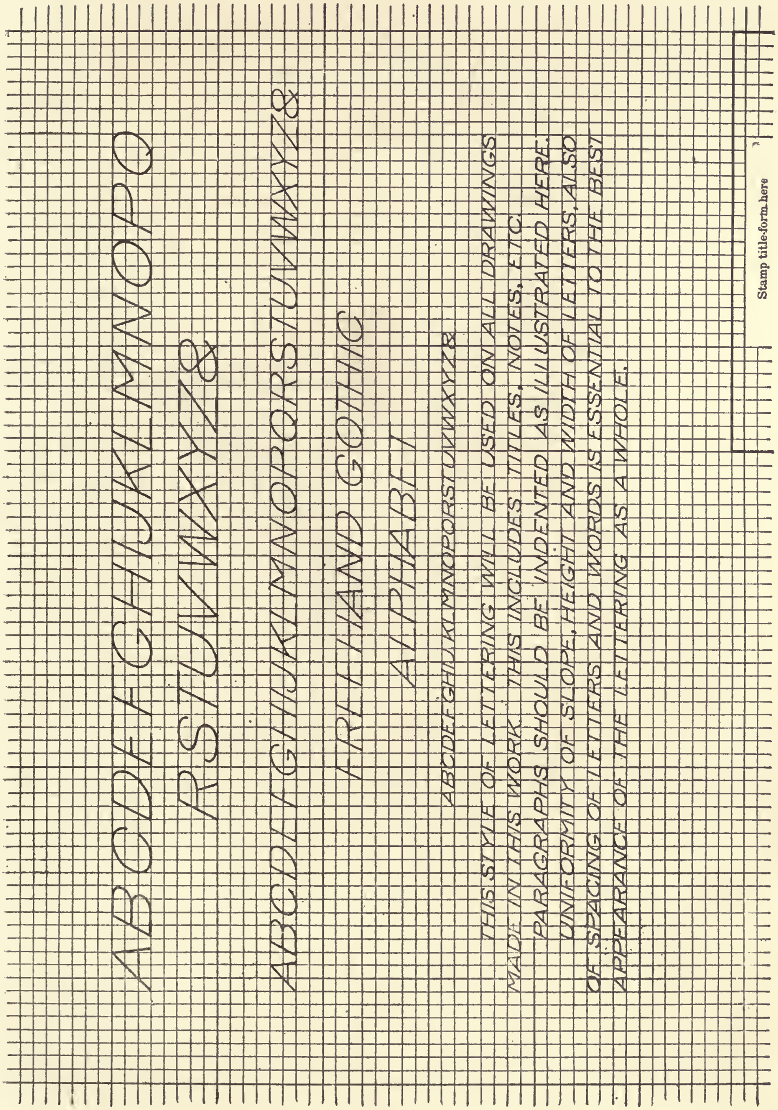
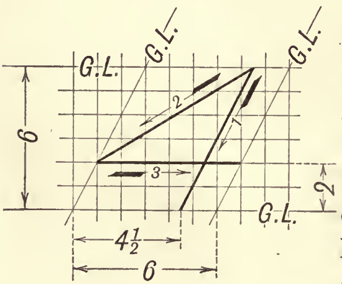


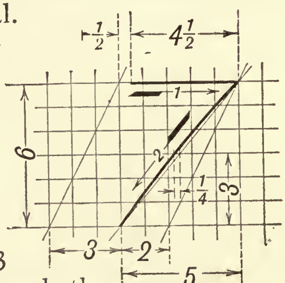

**Fig. 42. — Layout for Sheet C.**

for examination on the following paragraphs. Free-hand Inked Lines, page 136, § 96, Drawing Ink, page 18, § 18, The Ordinary Pen, page 18, § 19.

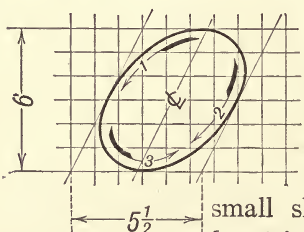
**44. Outline and Characteristics of Numerals.** For general discussion of guide lines, center lines, dimension lines, and arrows as used in connection with letters and numbers, see page 37, § 34.



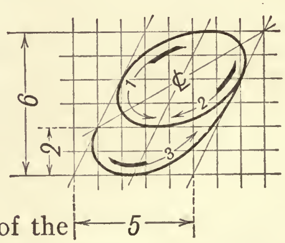

**Four.** 3 strokes. #1 is standard slope and its location in the limiting parallelogram of guide lines is very important, being a distance of three-fourths the total width of figure from the left guide line. #2 extends downward two-thirds the height of the numeral. #3 is horizontal and extends entirely across the limiting parallelogram and gives the figure its real width, which is greater than any other numeral.



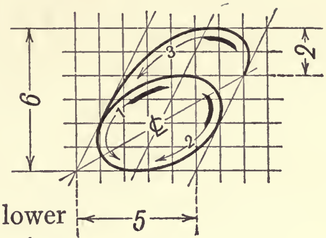

**Seven.** 2 strokes. Note especially the width of the numeral, the curvature of #2, and that the end of #2 does *not* meet the bottom guide line of the limiting parallelogram equally distant from the side guide lines.



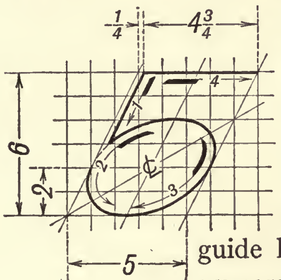

**Naught.** 3 strokes. Formed the same as the *O* (see page 51) but slightly narrower.



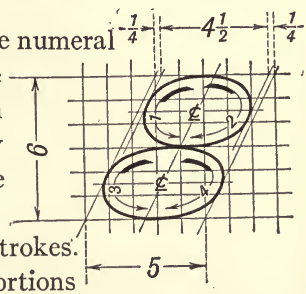

**Nine.** 3 strokes. A small sloping ellipse [see Fig. 40 (c)] forms part of the outline. Note especially the angle of the center line of the small ellipse and that the slope of the portion of the *large* ellipse is the slope of the numeral [see Fig. 40 (b)]. The form of the *9* is exactly the same as the *6* inverted (see page 59).



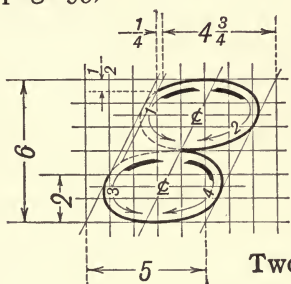

**Six.** 3 strokes. The form of the *6* is exactly the same as the *9* inverted (see page 58). This necessitates a change in the order of strokes.



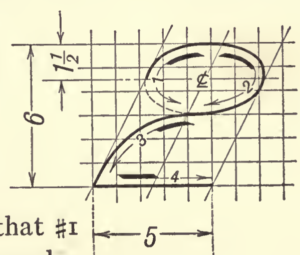

**Five.** 4 strokes. Lower part of *5* is similar to lower ellipse of *6* (see this page). #1 is standard slope, extending to ellipse only. Note that #1 is slightly to the right but *parallel* to the left-hand guide line and therefore is *not* tangent to #2. #4 extends to right guide line. Note that extreme width of the numeral is from starting point of #2 to right-hand point of tangency.




**Eight.** 4 strokes. The outline of the numeral is made up of two tangent ellipses. The lower half of the numeral is similar in outline to the upper half but slightly wider. Note the similarity to *S* (see page 53).




**Three.** 4 strokes. Consists of portions of two ellipses of the same dimensions. Note that less of the upper ellipse is used than the lower; this is in order that the numeral will not appear top heavy. The *3* is similar to the *8* (see this page).




**Two.** 4 strokes. The upper half of the numeral consists of part of an ellipse, which is one-half the figure height and the full figure width. #1 and #3 are both tangent to left guide line. Note the curvature of #3 and that #1 begins lower down than on the numeral *3* (see this page).

**45. Sheet D.** The purpose of this sheet is to teach the beginner the characteristics of the numerals and to give practice in making them. Locate the numerals on the sheet as shown in Fig. 43.

**The slope of fractions** must be the same as that of the alphabet; for example, take any ordinary fraction, say, five-eighths, the eight is not *vertically* below the five, but a standard slope line drawn through the center of the *5* passes through the center of the *8*. *The line separating the numerator from the denominator must always be a straight line parallel with the line of printing.* A sloping dividing line may lead to error in reading a fraction. The figures in the numerator and in the denominator must never touch the dividing line. **The total height of a fraction** should be about one and one-half times the height of whole numbers.

*Follow specific instructions given for preceding sheets* in so far as they apply to this sheet.

The title of sheet *D* is *NUMERALS.*

**46. Sheet E.** The purpose of this sheet (see Fig. 44) is to give practice in lettering of a size suitable for notes on working drawings.

*Follow specific instructions given for the preceding sheets* in so far as applicable.

The title of sheet *E* is *LETTERING.*

*Specific Instructions for Inking Sheet E.* Tack down the approved *penciled* sheet on the drawing board, and carefully ink each letter in the order in which they come. Clean the pen frequently and maintain a steady and even pressure on the pen point. Extra care must be taken in inking this sheet otherwise it is liable to be spoiled.

**47. The Small (or Lower-case) Letters of the Inclined Gothic Alphabet.** In studying characteristics of the lower-case alphabet, carefully read § 34, page 37, and remember that the direction and order of strokes is of prime importance. As in the case of free-hand capital letters, all strokes which are horizontal or nearly so are made toward the right, while all others are made downward or toward the draftsman. This avoids the possibility of catching the pen point in the drawing and splashing the ink.

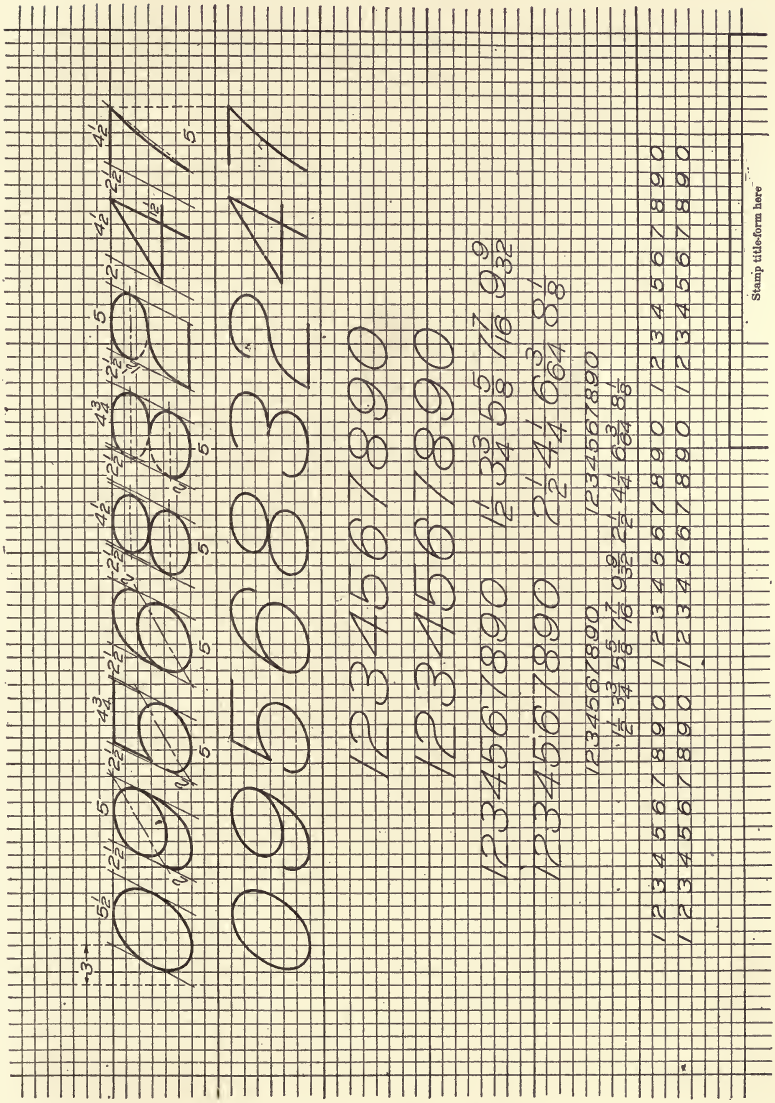



Fig. 43. — Layout for Sheet D.

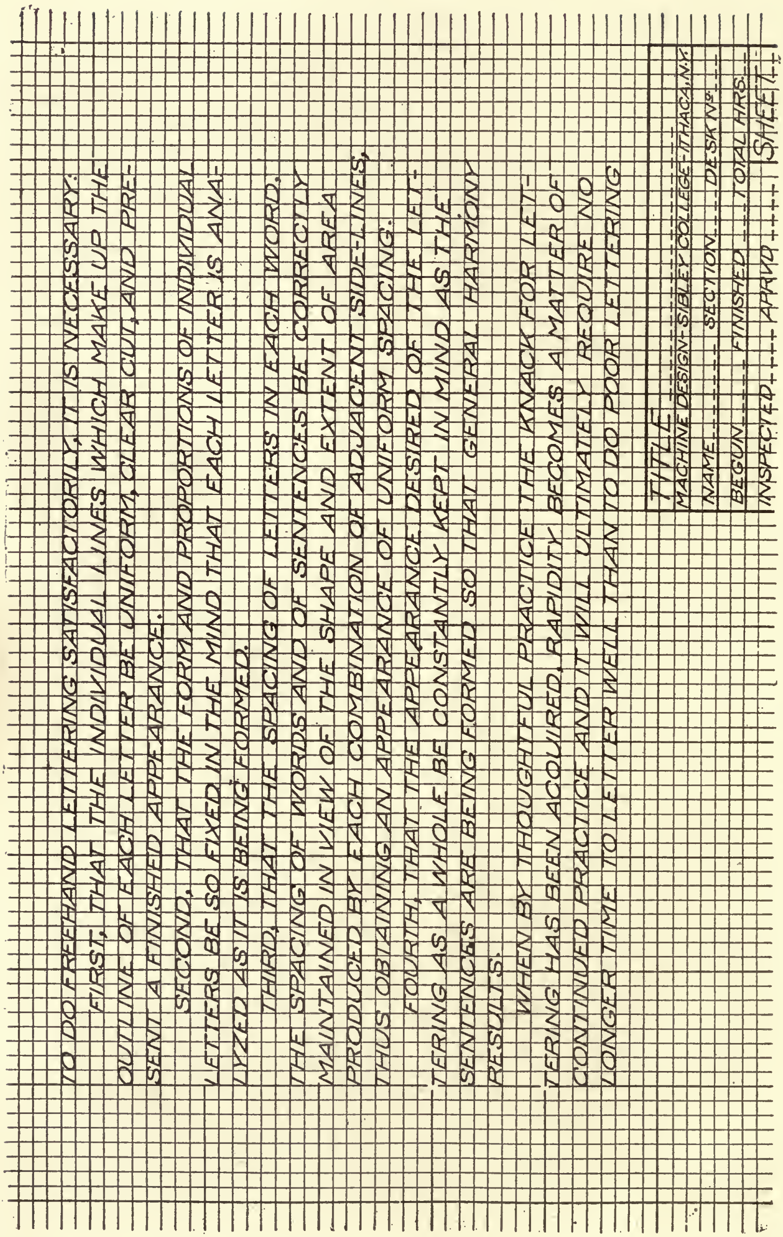
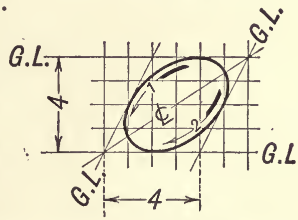


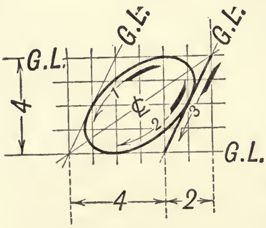

**Fig. 44 — Layout for Sheet E.**

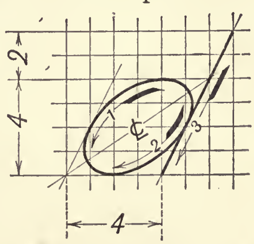
This alphabet requires a total height of eight blocks for the model letters, but in practice only four horizontal guide lines are necessary. These lines are numbered from the bottom to the top. Thus, #1 **limits** the letter when its stem (see page 37, § 34) extends below the body of the letter, as in *g, j, p, q, y;* #2 **limits** the bottom of the body; #3, **the top** of the body; and #4, **the stems** when they extend above the body, as in *b, d, f, k, h,* and *l.* The distance between the first and second lines and between the third and fourth lines is two spaces, or one-half of that between the second and third lines. The height and width of *a, c, e, n, o, u,* and *v* is the same and is equal to four unit spaces.

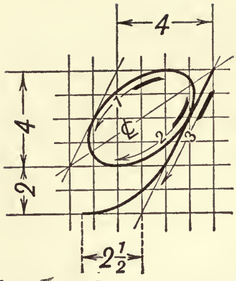



*The letter o* is similar to the sloping ellipse described in § 40, page 50, and makes up wholly or partially the outline of all letters having a body more or less elliptical. The horizontal and the slope guide lines form a parallelogram and the horizontal center line intersects these guide lines at their midpoints, which determine the touching points of the ellipse, but the *sloping center line* runs from the lower left hand corner to the upper right hand corner [see Fig. 40 (c), page 51]. Thus the small oval letters "tilt" more than the capital oval letters, though the slope of the letters *appears* the same. Consequently the small letters are more in harmony with the capital letters previously described. The small *o* is similar to the capital *O* (see page 51).

*Letters a, d, g,* and *q* differ as to the length and position of their stems. All these stems have standard slope and are tangent to the elliptical body at the same corresponding point. The vertical height of the elliptical body (or lobe) is equal to its width and is the same as for the *o* (see this page). The body of the *a, d, g,* and *q* should be made with two strokes, as shown; stroke #3 lies along the slope guide line.

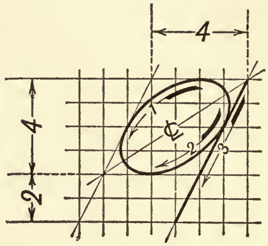


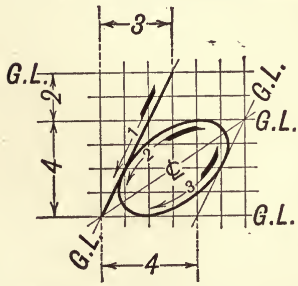


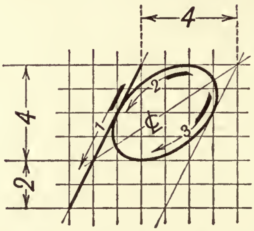

*d* repeats *a*, except that stroke #3 begins at guide line #4.

*g* repeats *a* but stroke #3 continues with a sweeping curve to guide line #1.




*q* exactly repeats the *a* construction but stroke #3 continues to guide line #1.

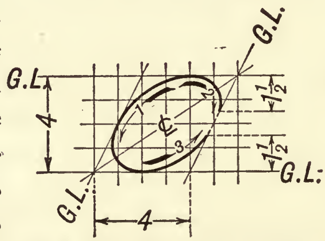


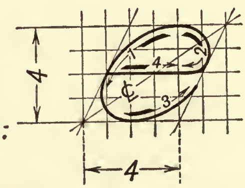




*Letters b and p.* The stem of the *b* is the first stroke and coincides with the left-slope guide line; stroke #2 ends at the touching point of the ellipse and left-slope guide line; stroke #3 continues to the stem.

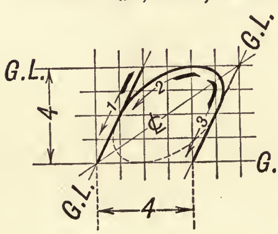
*p* differs from the *b* only in the position of the stem.

*Letters c and e.* The *c* has the same height and width as the *o* (see page 63), but the opening in the ellipse is such that strokes #2 and #3 begin at different touching points on the right-slope guide line. The small *c* is similar to the capital *C* (see page 52).



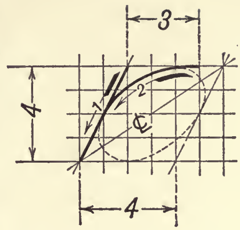




The *e* differs slightly from the *c* in that stroke #2 ends on the horizontal center line; stroke #4 starts from the point of tangency of stroke #1, and, following the center line, joins stroke #2.

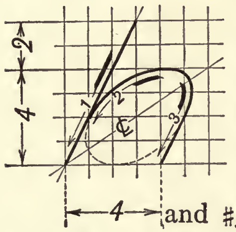



*Letters n, r, h, and m.* The curved portion of the *n* consists of the upper portion of the ellipse exactly as that of the *u* consists of the lower portion of the *o*. Stroke #1 is standard slope; stroke #2 ends where the ellipse comes

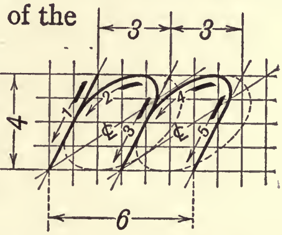
tangent to the left-slope guide line, and stroke #3 follows the guide line from the point of tangency. Strokes #1 and #3 must be parallel, beginning at their points of tangency with the ellipse.



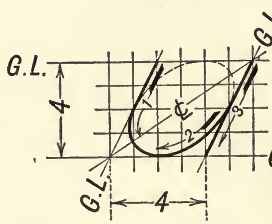

The *r* is the same as the left half of the *n* except that stroke #2 continues along the top guide line a short distance.

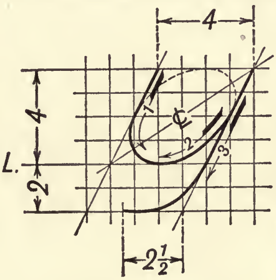



The *h* differs from the *n* only in the length of the stem, or stroke #1. Note that though the first three strokes of the *m* are similar to those of the *n*, the width is different; strokes #4 and #5 are a repetition of #2 and #3. All stems are parallel and have standard slope.




*Letters u and y.* The curved portion of the *u* consists of the lower part of the ellipse, exactly as that of the *n* consists of the upper portion of the *o*. Note that stroke #3 continues to guide line #2.



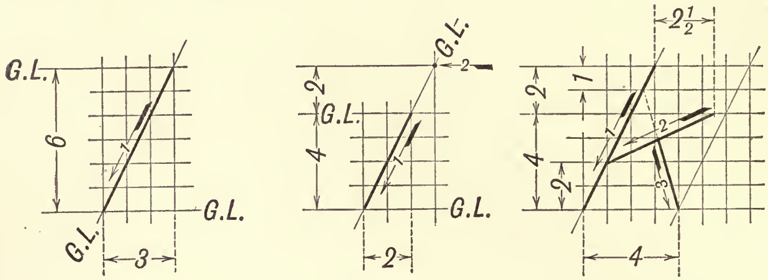

*y* repeats the *u*, but stroke #3 continues to guide line #1 exactly as in the *g*. (See page 64.)

*Letters l, i, k, t, f,* and *j*. The *l* is a simple standard slope line drawn toward the draftsman and is six spaces high.

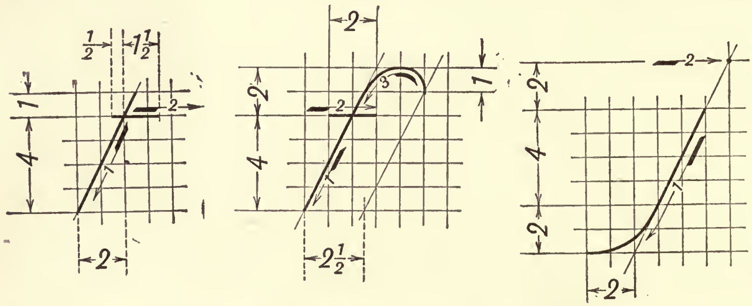
The *i* is a single stroke of standard slope, and the dot is placed exactly where the stem if extended would cut the horizontal #4.

The *k* has a standard slope line as stroke #1; stroke #2 starts on the horizontal guide line #3 but to the left of the slope guide line, so that the latter is *not* so wide at the top as at the bottom; stroke #3 begins *below* the middle of stroke #2, and extends to the

horizontal guide line #2, giving the lower part of the letter the standard 4-space width.



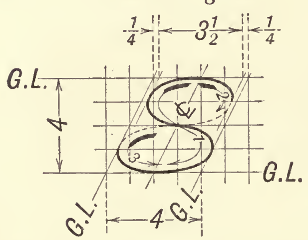
The *t* is five spaces high and has the standard slope. Stroke #2 is the horizontal cross-bar which coincides with horizontal



guide line #3 and which is two spaces long but is not bisected by the stem of the letter.

The *f* repeats the *t* except that by adding stroke #3 the letter is brought to the height of the *l*.

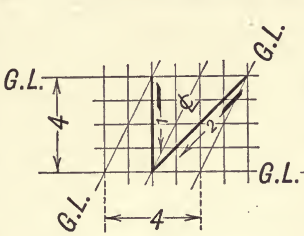
The *j* repeats the *i*, but is carried to the horizontal guide line #1 by adding a curve with a sweep one-half space less than the tail curve of the *g* and that of the *y*. (See pages 64 and 65.)

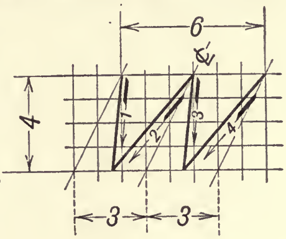


*Letter s.* The *s* is formed in three strokes. Stroke #1 is a double and reverse (ogee) curve which is horizontal at the top, bottom, and the middle for a very short distance. Strokes #2 and #3 are short curves from left to right. If the bottom oval of the letter should be completed it would be four spaces wide, while the upper oval would be only three and a half, thus making the

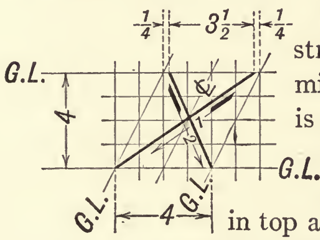
letter wider at the base than at the top. The small *s* is similar to the capital *S*. (See page 53.)

*Letters v* and *w*. The *v* contains the *only* vertical line in this alphabet which is stroke #1. It has full-letter width of four spaces at the top. The small *v* is similar to the capital *V*. (See page 46.)



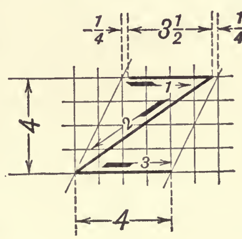




Stroke #1 of the *w* is *not* the same as stroke #1 of the *v*, nor is it twice as wide as the *v;* that is, the *w* is not made up of two v's. The small *w* is similar to the capital *W*. (See page 47.)




*Letter x.* The *x* is made with two strokes, intersecting slightly *above* the middle of the sloping center line. The top is three and a half spaces wide, while the bottom width is the standard four spaces. Note that this slight difference in top and bottom width is the same with the *s* and *z*. The small *x* is similar to the capital *X*. (See page 46.)

*Letter z.* The *z* is made up of three strokes. The top and bottom of the letter have the same widths as that of the *x* and *s*. The small *z* is similar to the capital *Z*. (See page 47.)




**48. Sheet F.** The exercises on this sheet (see Fig. 45) give practice in making the small letters of the Gothic alphabet and afford an opportunity to study in detail the characteristics of each of the lower-case letters. For detailed description see § 47, page 60. Note especially the relative size of capitals and numerals used with this alphabet.

*This sheet is to be inked* but is to be perfected and approved in pencil before inking is done.

*Follow the specific instructions given for preceding sheets* as far as applicable.

The title of sheet *F* is *LOWER-CASE LETTERS.*

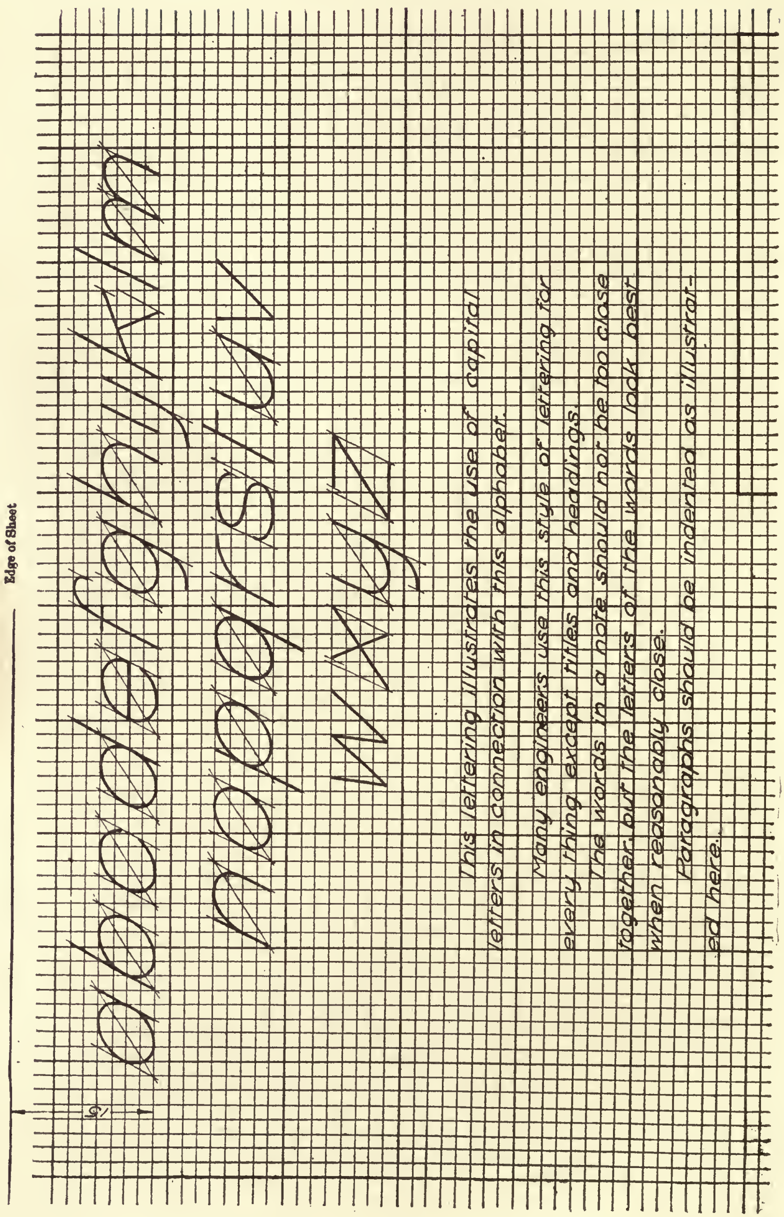



Fig. 45. — Layout for Sheet F.

**49. Designing Headings and Titles.** A very quick method of laying out the title is to sketch the lines of lettering on transparent paper of good quality and then transfer them in their proper relative position. **The transferring** is best done by blackening the back of the paper upon which the lettering is sketched, using a *soft* lead pencil sharpened to a chisel point and held flatwise. The paper is next placed in its proper position on the drawing and the outline of each letter carefully traced over with a moderately sharp pencil; this transfers the letters in dim lines. These outlines will not be so true as the original lines and must be gone over with a pencil before being inked.

After a little experience, a simple title can be made directly on the drawing by using horizontal guide lines and arranging the lettering symmetrically about a vertical center line. This lettering should be sketched in very lightly at first, and when correct the entire title should be retraced in pencil before being inked.

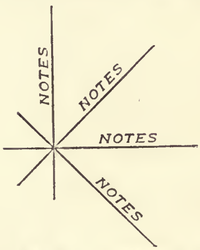



**Fig. 46.— Direction in which Inclined Lines of Lettering Should Read.**

When lettering a drawing if a name or a sentence cannot be printed in a horizontal line, the proper way to have the inclined lettering read is shown in Fig. 46.

**50. Sheet G.** The purpose of this sheet (see Fig. 47) is to give practice in laying out the bill of material and the title for a drawing. Before beginning work on this sheet read carefully § 49, this page. This sheet is graded upon the quality of the lettering, and the accuracy shown in locating the different lines of lettering.

*Follow specific instructions previously given* in so far as applicable.

NOTE. The straight border and limiting lines of the title form can be drawn by use of a straight edge, but they should be made neatly and in the exact location as shown in Fig. 47.

The title of sheet *G* is *TITLE FORM.*

**51. Examination on Chapter II.** Lay out a sheet of *vertical* Gothic letters or any other sheet of lettering assigned. Prepare for examination on the principal subject matter of this chapter.

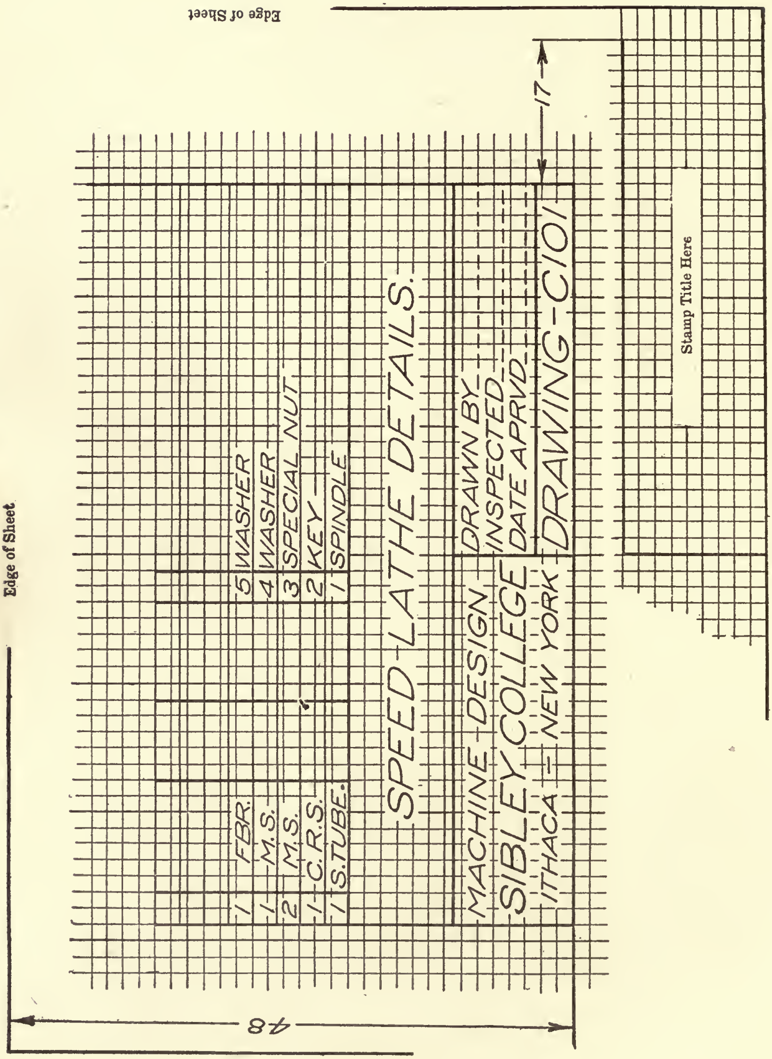



Fig. 47. — Layout for Sheet G.

# CHAPTER III

## MECHANICAL DRAWING AND DRAFTING ROOM PRACTICE

52. **Introductory.** The difficulty of describing an object so that its *form and proportions* can be completely understood and the object made by following the written description will be appreciated if such a description is attempted with reference to some comparatively simple object. The art of drawing is made use of to overcome these difficulties and drawing might be considered a " short hand " method of expressing form and proportion. The field of usefulness of drawing is very broad and the value of being able to draw and to read drawings becomes more apparent when it is realized that practically all buildings and construction, as well as most manufactured articles, were planned and drawn *before* their construction or manufacture was started. In studying this subject, the beginner should make every effort to become proficient in the *reading* as well as in the *making* of mechanical drawings. It is probable that most persons will never be called upon to make any but the simplest of drawings, but all those connected in any way with engineering work must be able to read them, and the ability to read drawings *quickly* and *correctly* is of the greatest value. There are several branches of drawing, and the branch to which the reader has likely become most accustomed is **perspective drawing** or, in other words, drawings which represent an object in a *single* view, as it would appear to the eye or in a photograph. A perspective drawing, however, is usually difficult to make and does not offer the possibilities for recording dimensions and other information which is often necessary to the engineer and which can be easily recorded on a mechanical drawing.

**A mechanical drawing** does *not* represent an object by a single view, as it would appear to the eye or in a photograph but represents it by a *series of pictures* termed "projected views " which

will be explained later. Each of these views represents some "face" of the object as it would appear if it actually existed in space, its appearance assumed to be unaffected by the laws of perspective. See § 53, page 73.

Briefly stated, a mechanical drawing must contain complete and absolutely accurate information of what is desired; every line on the drawing should be a fixed and measurable distance from every other line and should stand for something definite; the views, lettering, and dimensioning must be well arranged, and neatly and accurately done, so that the drawing as a whole will be exactly understood and present a pleasing and business-like appearance.

When lines cannot express *ideas* in a plain, direct, and unmistakable manner, abbreviations, symbols and printed notes must be used so that those who are to read or interpret the drawing will be in possession of all the information necessary to carry out every detail of the designer's or draftsman's wishes without further instructions, either written or spoken.

In just so far as a drawing fails to contain all necessary information in the best form possible it is unsatisfactory, regardless of how well it may conform to the principles of mechanical drawing or the degree of precision and elegance with which it has been made.

**Symbols on a mechanical drawing** usually consist of printed abbreviations or conventional signs, which signs are more easily drawn than the true form of the object to be represented. Thus, instead of representing screw threads in their *exact* form, as shown in Fig. 48, and which would be difficult and tedious to draw, especially on a small scale, the conventional method of representing ordinary screw threads, as shown in Fig. 49, is widely made use of in practical drawing rooms.

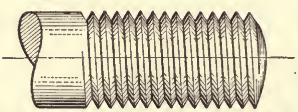
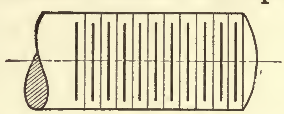


Fig. 48. — V-Thread, represented in Trued Form.



13 Thds. per Inch. L. H.

Fig. 49. — Threads Conventionally represented.

The relation of parts to one another, processes of manufacture, the final finish of surfaces, and similar data are indicated by notes, abbreviations and conventional signs.

**The printed matter** consists of dimensions, notes of instruction or specifications, names of parts, titles, and similar information.

Each of these three divisions — the drawing of the views, the application of conventional signs, and the composing and printing of notes, titles, dimensions, etc., — is in a way of equal importance, and it should be remembered that mechanical drawing, as it is generally understood and applied, especially in the manufacture of machinery, etc., is not intended to produce artistic effects, but to give instruction and to convey information of a *definite* character in the *simplest* way possible.

53. **Projection and Projected Views.** Mechanical drawing is based upon the principles of orthographic projection, and a knowledge of the fundamental principles of orthographic projection is necessary in order to understand even the simplest drawing. A short discussion is given here and a more extended discussion of this subject will be found in the authors' book on "Elements of Descriptive Geometry" and in other books on the same subject.

**Orthographic projection** consists in representing the form of an object as it would appear if projected upon two or more planes (termed planes of projection) at right angles to one another. The projecting is assumed to be done by rays of light respectively perpendicular to these planes and extending from the planes to the points on the object being projected.

One plane of projection is assumed in the position of an ordinary wall (i.e., vertical) and is termed **the vertical plane of projection,** the other occupies a position corresponding to the floor (i.e., horizontal) and is termed **the horizontal plane of projection.** Both vertical and horizontal planes of projection are assumed to be transparent, and every ray of light which extends from the vertical plane to a point of the object will be horizontal because all of these rays are perpendicular to the vertical plane; similarly the rays which extend from the horizontal plane to the object will be vertical. This is clearly illustrated in Fig. 50, where a part of the lathe is shown projected. The object which is shown projected is called the **Tool Rest Support Slide** and is shown in perspective in Fig. 112, page 150.

A careful study of this illustration will make clear the process of projecting *in space.* To produce a drawing by the principles of Orthographic Projection it is necessary to make further assumptions in order to establish a relation between the transparent planes at right angles in space and the drawing paper which is in a *single* plane. It is seen that the object is *behind* the vertical plane and *below* the horizontal plane, and this is termed **third angle projection.**

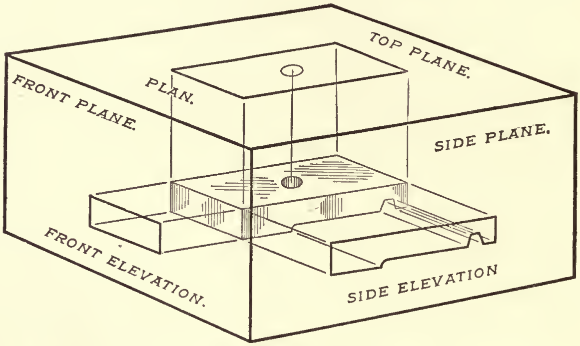
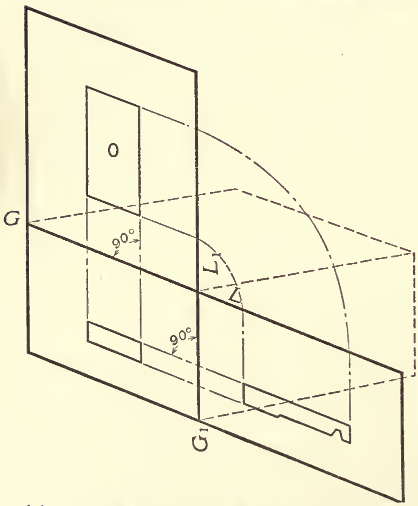
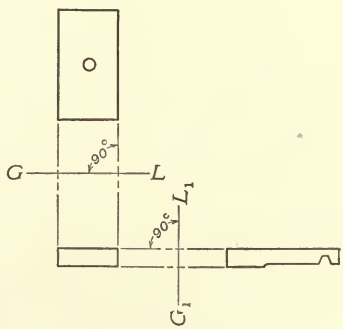



**Fig. 50. — Illustrating the Method of Orthographic Projection by the Use of Transparent Planes.**



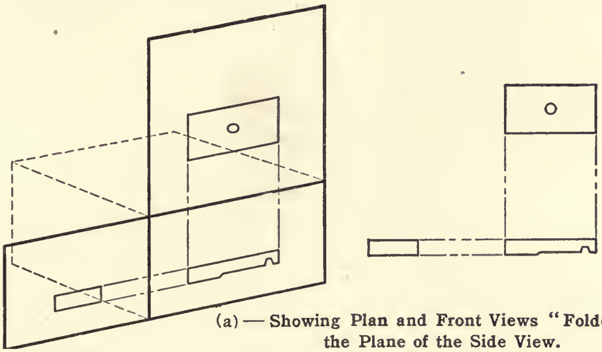

**(a) — Showing the Plan, Front and Side Views Brought into a Single Plane.**



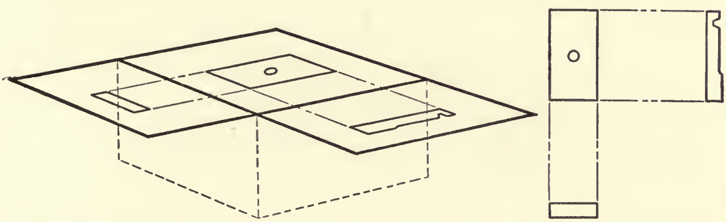

**(b) — Arrangement of Views Ordinarily Used in Making a Drawing.**

**Fig. 51. — Usual Relation of Views on a Flat Surface.**

Assume that after the views of the object are projected upon the planes these planes are unfolded so as to be brought to a *single* plane or flat surface, as shown in Fig. 51. This operation brings the top-view *above* the front-view, and the right-side-view to the *right* of the front-view. By connecting projections of *corresponding* points of the different views with straight dashed lines (as shown), it will be found that **these lines are perpendicular to the lines** ($G$–$L$ and $G_1$–$L_1$) which mark the *edges* of the planes of projection. These dashed lines serve to connect,



**(a) — Showing Plan and Front Views "Folded" into the Plane of the Side View.**



**(b) — Showing Front and Side Views "Folded" into the Plane of the Plan View.**

**Fig. 52. — Various Arrangements of Views.**

from one view to another, points which are projections of a *single* point on the object represented. They are the same length as the projecting rays of light and *represent* them on the drawing paper. The relative position of the different views as shown in Fig. 51 is a very common arrangement in practice, but the arrangements of views as shown in Fig. 52(a) and 52(b) are equally correct and may be used if for any reason they are found more convenient. The top view is known as the **plan,** and the side or front views as the **side elevation** or **front elevation.**

**54. Conventional Lines.** If all the lines of a drawing were *identical* in character, that is, unbroken throughout their length and of the same *weight*,[1] the drawing would be lacking in contrasts and would be difficult to read. This difficulty is overcome by using lines of different construction and weight for different purposes. For example, solid unbroken lines (called "visible lines") of fair width are used to represent visible parts of an object; fine lines (called "invisible lines") composed of short dashes are used to represent invisible parts. Dimension lines are unbroken (except for the dimension figures) but are not so prominent as the lines representing visible outlines of the object.

The meaning of the *construction* of the various lines is given below, but no single rule can be stated as to the proper *weight* of the different classes of lines since this depends on circumstances.

**The visible line** is an *unbroken, heavy line* used to represent the outline of the object and the surfaces that are in full view

Fig. 53. — "Standard" Visible Line.

of the draftsman. The weight of the line must be varied at times, depending on the size and the accuracy required of the drawing, but the standard weight is shown in Fig. 53.

**The invisible line** is used to represent the parts of an object which are hidden or invisible to the draftsman. Such lines are *broken* into short dashes about one-eighth inch long, separated by spaces of one-half this length, and are only about two-thirds

Fig. 54. — "Standard" Invisible Line.

the weight of the visible lines. When an invisible line is very short, the dashes and spaces must be shortened accordingly. Dashes must be made of one length and spaces of another, the spaces always being smaller than the dashes (see Fig. 54).

[1] The *weight* of the line determines its prominence. Variation in weight is secured by making the line of different widths if drawn with ink, and by making it lighter or darker in color by varying the pressure and hardness of the lead if drawn with a pencil.

**Section lines** (see Fig. 55) are drawn parallel and usually close together (say, $\frac{1}{16}''$ to $\frac{1}{8}''$) and covering those areas which are assumed cut and exposed to view. They are *light weight continuous lines* in construction. (See Fig. 63, page 81.)

Fig. 55.—"Standard" Section Line.

**Dimension lines** (see Fig. 56) are for the purpose of indicating the *limits* between which dimension figures apply. Dimension lines are drawn *light weight and are unbroken* except for

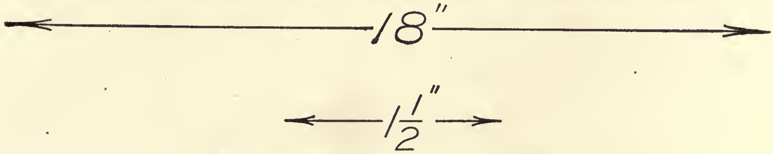
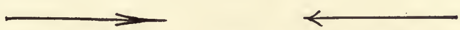



Fig. 56.—"Standard" Dimension Line.

a distance, usually in the center, to allow for the dimension figures. *Under no circumstances should this line pass through the dimension figures.*

**An arrowhead** is drawn at the end of a dimension line to indicate its extremity and the place to which the dimension applies.

Arrowheads appear much better when drawn long, sloping,



(a) Correct. (b) Incorrect.
Fig. 57.—Arrowhead.

and narrow, as shown by Fig. 57(a), and they should *not* be drawn spreading, as shown by Fig. 57(b).

**Reference lines** extend out from a part to be dimensioned to receive the arrowheads at the ends of the dimension lines. They consist of groups of three dashes — two short and one long — repeated as often as necessary to make the line as long as re-

Fig. 58.—"Standard" Reference Line.

quired. The line should begin with the two short dashes and end with the long one, and the relation between short dashes, long dashes, and spaces is the same as in center lines. (See page 78.) *A short space should always separate the reference line from the object.* Fig. 58 shows the standard reference line.

**The center line** is a line around which a sketch or drawing is "built," and is usually an axis of symmetry. It is composed of short and long dashes. The short dashes are about one-eighth inch long, and the length of the long dashes will depend on the size of the drawing. The space separating long and short dashes is about one-sixteenth inch. (See Fig. 59.)

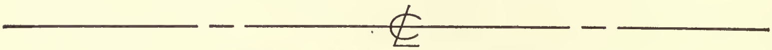


**Fig. 59.—"Standard" Center Line.**

The center line of a part not detailed is often shown on a drawing in its true relative position to the parts that are drawn. In such a case the symbol ℄ is written across the center line of the part not detailed, but this symbol is *not* used on center lines of parts that are drawn. Thus, on part No. 1 of drawing C–101 (see page 118, Fig. 82) the center line of the shaft is not marked, but the positions of the bearings are located by drawing their center lines and marking them *℄ OF BEARING.*

Some drawings do not require center lines, while others may require several, depending usually on the number of axes of symmetry. The center-line construction is also used to indicate the location of a cutting plane in making a cross-sectional view, and the two *should not be confused.*

**All finished lines, whether drawn free-hand or mechanically, with pencil or with ink, must be:**

(*a*) *Clear cut.*

(*b*) *Free from waves.*

(*c*) *Of the same width throughout.*

(*d*) *Colored to the same degree throughout.*

**A line is clear cut** when the edges are free from irregularities, that is, when the outer edges are not "ragged" or "sketchy."

**A line is free from waves** when it does not deviate locally from the general direction it should follow. Both the wavy and the ragged free-hand lines usually result from holding the pencil, or particularly the pen, with such a *tense* grip as to cause the hand to tremble. Hold the pencil or pen easily, as you would in ordinary writing.

**A line is of unvarying width** when the outer edges run parallel throughout its length.

**A line is colored to the same degree** (i.e., of even color) when the coloring matter (such as lead or ink) is evenly distributed throughout the line. To avoid making a pencil or ink line appear dark at one point and light at another, that is, variable in degree of color, apply *even pressure* in making the finished line, and in inking maintain a uniform flow of ink by frequently cleaning and refilling the pen.

**55. Sectioning and Sectional Views.** If an object has hollow portions it is often necessary to know the *exact* form and the dimensions of the interior.

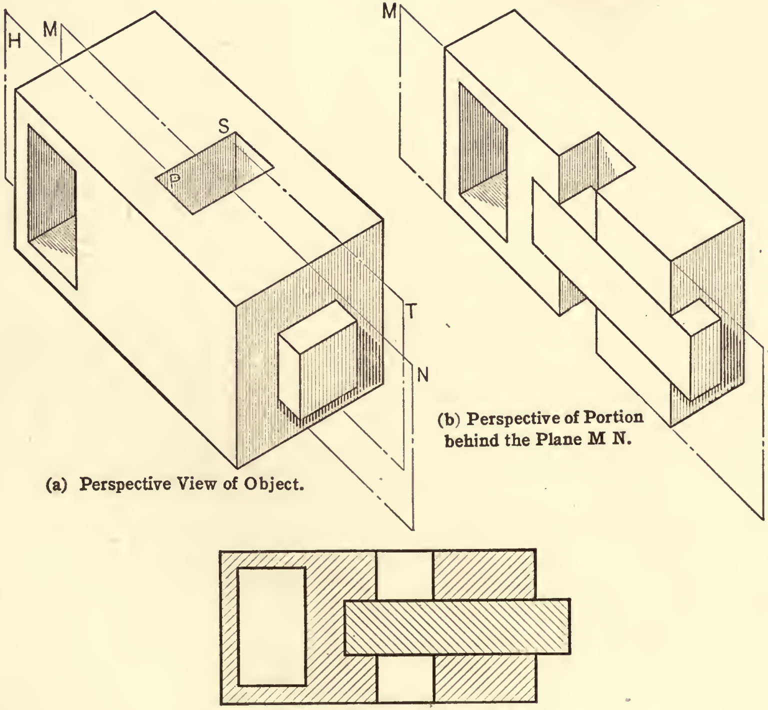
Since invisible portions of an object are represented on drawings by means of broken lines, views which represent the exterior or visible portion and at the same time attempt to show the interior form of an object are frequently complicated and hard to read. To overcome this difficulty it is often convenient to imagine the object cut open with a saw [see page 80, Fig. 60(a) and 60(b)] and then represent it as if the plane of the cut *MN* were an *outside* surface of the object. [See Fig. 60(c).]

Such a view of an object is termed a **sectional view, a cross section,** or simply a **section of the part.** If a section is taken in the direction of the length of an object, it is termed a **longitudinal section;** if taken perpendicular to the length, it is termed a **transverse section.**

A complete section is not always assumed in a *single* plane, but may be made up of partial sections in *several* planes. A built-up cross section is intended to give information in such a way as to make it unnecessary to draw several cross-sectional views or perhaps a complete view of the object. In Fig. 61 the cutting planes move along the line *HPST* and the section should be referred to as the section *HPST*.

The method of accurately determining complicated sections in true projection is beyond the scope of this work and is explained more fully in the authors' book on "Descriptive Geometry" and in other books on the same subject.

**In order to make sectional views easily understood,** the different *kinds* of material assumed to be cut are sometimes indicated on the drawing by conventional methods. The usual

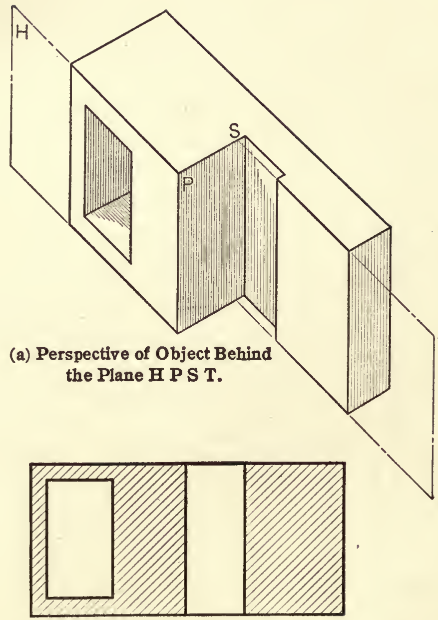



(a) Perspective View of Object.

(b) Perspective of Portion behind the Plane M N.

(c) Section Cut by the Plane M N.

Fig. 60. — Illustrating the Meaning of a Simple Section Through an Object.




(a) Perspective of Object Behind the Plane H P S T.

(b) Section Cut by the Planes H P S T.

Fig. 61. — Illustration of the Meaning of a Compound Section Through an Object.

method is termed sectioning and consists of various combinations of spacing, and light and heavy weight lines drawn parallel and covering the area which represents the surface assumed to be cut and exposed to view. No uniformity exists in practice as to the combination of lines and spaces that shall represent a particular material. Those combinations given in Fig. 62 are fairly general in their application, but it is readily seen that, because of the great variety of materials in use and the fact that

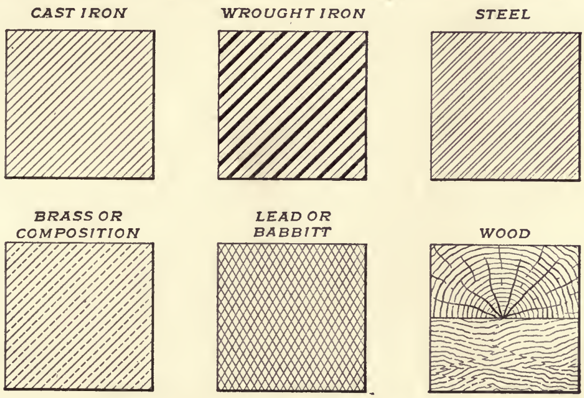
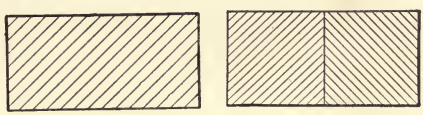



Fig. 62. — "Conventional" Sectioning.

new materials are constantly being introduced, it is better practice to use only the simple parallel lines [see Fig. 63 (a)] and then designate the material by writing its abbreviation (see page 103, § 67) on the ruled surface or in some other simple manner. **Where a number is used to indicate a material,** it has the advantage that the number can also represent the quality, heat treatment, etc., or, in the case of alloys, the composition. The number therefore does not only represent the *name* of the material but also its *properties* — both physical and chemical — and in reality is a specification number. A further advantage of this method is that, should the material originally called for prove unsatisfactory, as is frequently the case, a change in the number can be made on the drawing without erasing the section lines.



(a) Ordinary Sectioning. (b) Sectioning Adjoining Pieces.

Fig. 63. — Sectioning.

**Section lines of adjoining pieces** [see Fig. 63(b)] **are drawn in** different directions, if possible, so as to more clearly define the limits of the parts.

**Section lines should be drawn at 45° to the horizontal** whenever possible, and should be made about one-half the weight of the lines used to represent the outline of the section. **To section an area evenly** requires practice and a steady hand. Beginners usually make the mistake of drawing the section lines too close. Also the tendency is to *vary* the distance between section lines, usually increasing the spacing as the work proceeds. Such sectioning is unsatisfactory, and can be avoided by glancing back over the completed area for each eight or ten lines drawn, thus *bringing to mind* the original unit of spacing. If a section line has been drawn too far from the preceding one, the next line should be drawn at a distance *less* than the unit spacing; this has the effect of giving an even appearance and the normal spacing should then be continued.

**The spacing between section lines** should be $\frac{1}{16}''$ to $\frac{1}{8}''$, depending upon the size of the cross section, but *must be* the same throughout the area of any *single* part being represented in section. To insure uniform spacing, draftsmen sometimes use **section liners.** The simplest form, and one easily made, is shown in Fig. 64. It consists of a small straight-edge cut out to receive one side of the triangle. The length of the slot portion is equal to the length of the side of the triangle plus the approximate distance desired between the section lines. To use this device, place it on the drawing with the triangle against the left-hand stop, as shown in Fig. 64; draw a line along the slope side; hold the triangle stationary with the fingers of the left hand, and with the thumb move the strip to the left until it is stopped by the triangle. Next hold the strip stationary and slide the triangle until it comes in contact with the left-hand stop of the strip, and draw the second line. This process is repeated until the sectioning is completed. **When the section is very large,** the section lining is sometimes placed

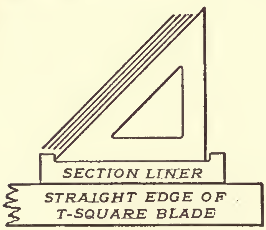



Fig. 64. — Section Liner.

at the edges only, as this saves time and usually gives a better appearance; in such cases the distance between the section lines would be increased somewhat.

**Sectional views may be drawn in any suitable position** on the drawing, but it is always best to locate them as close to the place at which they are taken as is convenient. **To indicate the location of the section,** a line must always be drawn across the original view of the object, and the extremities of the line (which represents the cutting plane) should be lettered as shown in Fig. 85, page 123.

It is not always necessary to draw the cross sectioning over the entire surface that lies within the cutting plane, and in general **such details as a shaft, key, bolt, gear tooth, rib or arm of a wheel, are not sectioned.**

**Where a part shown in section is symmetrical about a center line,** such as a part turned on a lathe, a half or a quarter longitudinal section, together with an end view, is often the best choice of views. Thus, a drawing of the Tail Stock Spindle (see Fig. 103, page 144) or the Shell (see Fig. 104, page 144) would usually consist of an end view and a top or side view shown in section; that is, the Spindle is assumed to be sawed in two lengthwise, the front or top half removed, and a drawing made of the remaining half as it appears when looking directly at the cut surface.

When a drawing is made of an object assumed to be so cut that one-fourth of the piece is removed, the view is termed a **quarter-section view.**

Sometimes by *turning up* a section directly on the first view space is saved and a second view of a part is unnecessary. In such cases all the lines of the original view must be drawn in, even though they may conflict somewhat with the lines of the turned up section. (See Key shown in Fig. 82, page 118.)

**56. Number and Arrangement of Views.** There is always a *choice* of views, and those views should be made which convey the greatest amount of information consistent with clearness. In determining the number of views required, the purpose of the drawing, the form of the object drawn, and the character of the views must all be considered. The **rule to be followed as**

**to the number of views** is that there shall be the *least number* made to accomplish the purposes of the drawing. **In general, three views of an object are sufficient** to illustrate its form and the processes necessary in its manufacture. If, however, its construction is complex, it may require sectional views in addition to the three general views ordinarily taken. If the part is quite simple and symmetrical, — as, for example, a washer, bolt, screw, shaft, plain key (see Fig. 82, page 118), — a **single view** is sufficient. The draftsman should imagine himself reading the drawing, and make as many views (and no more) as are necessary to give complete information in a clear and unmistakable manner. While making or checking a drawing if the question arises as to whether certain views or cross sections are needed in order that the drawing may convey all information necessary, these views or sections should always be drawn, for it is reasonable to assume that any point of uncertainty not fully cleared up by the draftsman or checker leaves the way open for those using the drawing, especially for the first time, to make mistakes. An effort on the part of the draftsman or checker to rush work or "save" time often leads to costly errors on the part of those who must work with the drawing, besides causing a loss of time by each person who must read the drawing. A note should be used when it will save drawing a view. In general, several sections are preferable to a single view containing many dashed lines.

**The arrangement of the views** must be such that their relation to one another will be what is technically termed **third-angle projection** (see page 74, § 53). Sectional views and other auxiliary views should be placed close to the main view of the part which they partially represent.

Where practical the main views of an object should represent it in a similar position to that which it will occupy *on the machine*, that is, a part should not be represented upside down, etc.

The different views should be arranged symmetrically on the sheet, in order that space may be used to the best advantage and that the drawing as a whole may present a pleasing appearance.

This can be accomplished best by **blocking out the sheet** with free-hand rectangles, drawn to scale, to include each view (see page 93, § 61). These should be sketched in very lightly,

and, after provision has been made for all the views, if the rectangles are not well distributed they can be easily rearranged.

57. **Detail Drawings.** A detail drawing is one which represents a single part and contains all information necessary for its manufacture. Before a detail drawing is made, therefore, an experienced draftsman will determine exactly and to the minutest detail the purpose of the finished part and the shop operations necessary to produce it. It often occurs that the draftsman knows exactly what is wanted in the finished part but has not had *sufficient shop experience* to know the best method of producing it. In such cases this information should be obtained from a reliable source before the drawing is carried too far. Generally a single detail drawing serves for all departments of a manufacturing plant, but it may happen in complex work that different details are required for the different *classes* of workmen, such as the pattern maker, the blacksmith, the machinist, etc. Such drawings give the dimensions and notes required only by the particular class of workmen for whom they are intended.

**The number of parts detailed on a single sheet** will depend on circumstances, but it is becoming more common to detail each part on a separate sheet. This method has the advantage that fewer workmen are affected in case a drawing has to be recalled for any reason. Also, as the drawing can be easily and quickly obtained, the chances of costly mistakes are lessened in case a change must be made on a part. In cases where an article is standard and is produced in great quantity it is sometimes advisable to represent a part on several sheets called **operation sheets,** that is, a drawing which shows only the operation to be performed on the part by a single workman. In establishments where a system of representing several parts on a single sheet is practiced it is customary to *group* parts in a logical manner; for instance, parts which fit together may be detailed on the same sheet, say, in the case of the lathe the details of the Headstock might make up one sheet; parts made of the same material, such as cast-iron parts, might be grouped; or parts which are manufactured by similar processes, and hence in the same shop department, are detailed on the same sheet. If parts

which fit together are detailed on the same sheet they are more easily checked, but in practice it is often difficult to maintain a *fixed* system of grouping. Certain advantages are to be gained by the beginner in grouping detail drawings and hence several parts will be shown on a single sheet in this course rather than each part drawn on a separate sheet.

In making a detail drawing, roughly "block out" in very light lines the different views in their approximate relative location on the sheet *before* beginning the actual pencil drawing.

It is usually better to work up all the views of a part at the same time rather than to endeavor to complete one view and then pass to the next. As a rule, one part should be detailed completely, including all its views, dimensions, notes, etc., before the detailing of another part is started.

**58. Assembly Drawings.** The detail drawings show the form and size of each part but give no idea how the various parts fit together or how the machine or structure as a whole will appear. The assembly drawing illustrates the general design of a machine or structure and contains information which enables a workman to sort out the finished parts and assemble them into the machine. The assembly drawing is, therefore, a representation of the completed machine or structure with all its parts collected and arranged in their proper relation to one another. *It should be drawn part by part from the detail drawings* and serves as a last check that all parts fit together. Such drawings may show some detail, but too much of the inside construction should not be shown (in dashed lines) or the drawing may be difficult to read. If the machine is complex two or more views and cross sections through several parts may be required, in order to give all necessary information and still avoid too much dashed-line construction. Such minor parts, as bolts, nuts, screws, keys, etc., are seldom drawn in detail upon the assembly drawing, but their position is usually indicated by center lines.

Only over-all and important main dimensions should be given on assembly drawings. It sometimes adds to the value of an assembly drawing to give parts a reference number or letter so that they can be easily referred to. See page 104, § 69.

**59. Conventional Methods.** As has been stated elsewhere, the purpose of a mechanical drawing is to give instruction and information, and not to produce elaborate picture effects. For this reason it is often best to represent an object by as few lines as possible if in doing so clearness is not sacrificed. Such *abridged methods* of representing forms and constructions on a drawing are termed "conventions" or "conventional methods" and are universally used to represent details that are of frequent occurrence, such as screws, bolts, threads, etc.

Conventional methods may be used in several ways, for example, as a drawing which approximates the form of the object being represented; cross-sectioning, shown in color or by lines which symbolically represent the materials; methods of representing the planes in which an object is assumed to be cut; the path and the direction of motion of a moving point; shop operations, such as the finish of surfaces, etc. Unfortunately no list of conventions can be universally adopted, and upon entering the employ of a company the draftsman must study and adhere to their particular system. Fig. 65, page 88, illustrates common conventions, some of which are used in this course.

**Group A, Fig. 65, shows the following conventions:**

1. Method of **representing a shaft** of circular section so that space can be saved on the drawing. This method of representing an object, as if a portion were omitted, cannot be used unless the form of the portion omitted is exactly the same as the part shown. Thus, that portion of a shaft with a keyway could not be omitted in any way that would leave any information as to the dimensions and location of the keyway lacking.

2. Method of **representing a bearing.** Note that the distance between bearings is given from the center line of one to the center line of the other.

3. Method of **representing the broken end of a timber** viewed from the side, also method of showing cross section of timber.

**Group B shows the following conventions:**

1. Method of **representing a long hollow part** and contracting the drawing lengthwise. The break differs from that of the shaft in that the proportional thickness of the shell is shown.

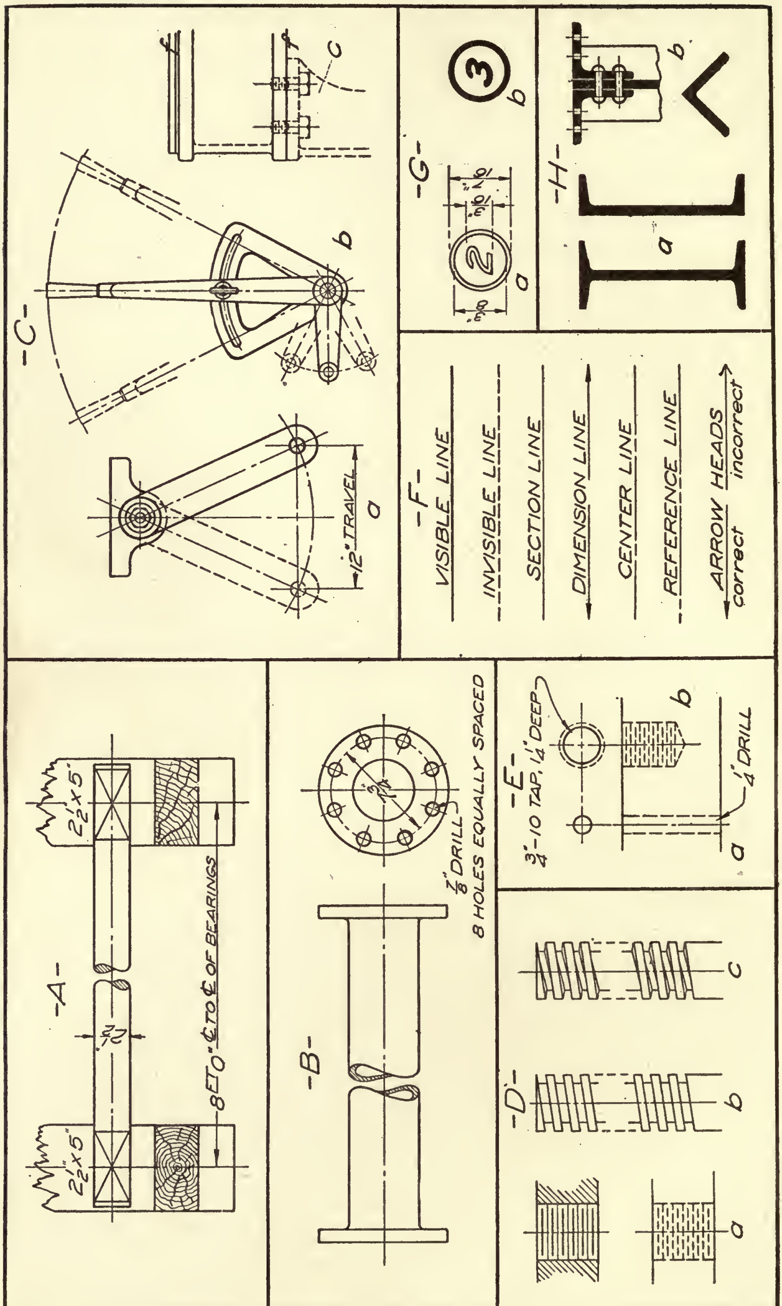



Fig. 65.—Common Conventions.

2. Method of **dimensioning a series of holes** equally spaced around a circle. Note that the holes are spaced each side of the vertical and horizontal center lines, and not on these center lines.

**Group C shows conventional uses of broken or dashed lines** which are distinct and *must not be confused* with the conventional method of representing the invisible lines of an object. See page 76, § 54.

(a) Shows a method of **representing a moving arm when in its extreme positions,** one position of the arm being represented by full lines, the other by dashed lines.

(b) Shows a lever in its central position and the outline of the lever is shown by broken lines in each of its extreme positions. In designing and in bringing out certain information clearly it is often best **to represent a part in several positions.** In checking the drawing of an assembly of parts this method is effective in making sure that parts which change position do not interfere at any time during a complete cycle.

(c) This shows the conventional method of **representing a part not completely drawn,** and which is adjacent to the part drawn.

**Group D shows the conventional methods of representing screw threads.**

(a) Shows the **conventional method representing the visible and invisible V threads.** In each case the threads begin and end with the *short* line, and in the invisible or dashed threads the dashes of one line are opposite the spaces of the adjacent lines. The short lines represent the bottom line of the V and should be of equal length; all long lines representing the top line of the V should be drawn to meet the side lines. Note that the short lines in the visible thread are about twice the weight of the long lines.

(b) Shows **the conventional Square Thread.**

(c) Shows **the conventional National Acme Thread.**

Where a part is threaded for some length it is customary to show only a few threads at the beginning and at the end of the threaded portion, thus saving time without sacrificing clearness. The threaded portion can be represented to scale or may be

shown broken, as in the case of a shaft, etc. See Group A–1, § 59, page 87.

**Group E shows the conventional method of representing a drilled hole, a "tapped" or threaded hole.**

1. If the hole is comparatively small a note usually states the size and the fact that the hole is drilled and a leader is drawn from the note to the place where it applies.

2. If the hole is to be tapped a note stating the size of drill to be used, depth of hole, number of threads per inch and the form of thread is printed and a leader run to the place where the note applies.

Thus, a note written $\frac{13}{64}''$Drl $\times \frac{3}{8}'' \times$ 16 U. S. tap would indicate that the hole is to be $\frac{3}{8}''$ deep and the standard tap to give 16 U. S. threads per inch is to be used.

**Group F shows conventional lines** as ordinarily used in drawing. This subject is taken up on page 76, § 54.

**Group G** shows the method of giving **reference numbers.** This subject is taken up on page 104, § 69.

**Group H shows the usual method of indicating a cross section of structural sheet steel, also steel shapes,** such as boiler plate. Instead of section lines being used, the cut surface is made solid black. Note that in the case of several pieces being bolted or riveted together, they are shown slightly *separated*, since this adds to the clearness of the drawing.

**60. Drawing to Scale.** Usually in making a drawing the object can not or need not be represented *actual* size, and in order to get the drawing on a piece of paper of convenient dimensions, it must be made "to scale," that is, the actual measurements on the drawing must bear some fixed ratio to the corresponding measurements on the object. The method of making a scale to such a ratio is to choose an arbitrary distance and let that distance *represent* one foot. This distance which represents one foot is then divided into twelve equal divisions, each of which therefore represents one inch. *One of the twelve divisions* is then divided into halves, quarters, eighths, etc. (see Fig. 31, page 30), to *represent* one-half inch, one-quarter inch, and so

on, until such subdivisions become too small to be conveniently read. To illustrate, suppose a drawing is to be made one-fourth size. To *compute* the length of every line on the drawing would be a slow and tedious process, and would require that every dimension on the object be divided by 4 to get the corresponding dimension on the drawing. To overcome the necessity of making such computations, imagine an ordinary foot rule *uniformly* compressed until exactly one-fourth its original length. It would then be only three inches long but marked "twelve," and the divisions marked "one inch" would actually be one-quarter of an inch long, those marked "one-half inch" would actually be one-eighth, etc. That is, all the dimensions would be reduced to one-quarter size and any desired dimension, such as $5\frac{7}{8}$ or $9\frac{3}{8}$, etc., could be marked off or read directly upon the drawing (which is one-quarter size) with this compressed rule and *no computations whatever would be necessary.*

SCALES IN COMMON USE

| Actual Measurement on Drawing. | Actual Measurement on Object Represented. | Size of Drawing Compared with Actual Size of Object Represented. |
|---|---|---|
| $\frac{1}{8}$ inch | One foot | $\frac{1}{96}$th size (0.010) |
| $\frac{1}{4}$ inch | One foot | $\frac{1}{48}$th size (0.021) |
| $\frac{3}{8}$ inch † | One foot | $\frac{1}{32}$nd size (0.031) |
| $\frac{1}{2}$ inch | One foot | $\frac{1}{24}$th size (0.042) |
| $\frac{3}{4}$ inch † | One foot | $\frac{1}{16}$th size (0.063) |
| 1 inch | One foot | $\frac{1}{12}$th size (0.083) |
| $1\frac{1}{2}$ inches * | One foot | $\frac{1}{8}$th size (0.125) |
| 3 inches * | One foot | $\frac{1}{4}$th size (0.250) |
| 4 inches † | One foot | $\frac{1}{3}$rd size (0.3330) |
| 6 inches * | One foot | $\frac{1}{2}$ size (0.500) |

* Desirable scale for ordinary use. † Rarely used.

The above table should be thoroughly understood as *beginners are often misled by the way the instrument is marked.*

For example, the "$\frac{1}{4}$" marked *on the instrument* does not indicate that this scale is for making a drawing $\frac{1}{4}$ size, but that $\frac{1}{4}$ inch

has been divided to represent some convenient division of inches in one foot. This scale of $\frac{1}{4}$ inch to the foot is $12'' \div \frac{1}{4}'' = \frac{1}{48}$ full size, while the $\frac{1}{4}$ size would be $12'' \times \frac{1}{4} = 3''$, or a scale of $3''$ to the foot. Another fact to remember is that dimension numbers which the draftsman prints on the drawing are the *actual* dimensions as measured on the object represented, and not the distance obtained by measurement on the drawing with the ordinary foot rule unless the drawing *happens to be full size.*

**The scales most used in practice** are full size, or 12 inches equals 1 foot; one-half size, or 6 inches equals 1 foot; one-fourth size, or 3 inches equals 1 foot, and one-eighth size, or $1\frac{1}{2}$ inches equals 1 foot. If an object is very small the scale of the drawing may be *increased* in order to make a satisfactory drawing. For example, twice size would mean 12 inches on the drawing represents 6 inches on the object. It is often useful to be able to *read these scales directly from the foot rule* and not be dependent upon the special graduation. This is easily done by remembering that for a scale of 6 inches to the foot, 1 inch will be represented on the scale by $\frac{1}{2}$ inch, and reading each $\frac{1}{2}$ inch as 1 inch, the subdivisions of the foot rule would read as follows: $\frac{1}{4}''$ on the drawing $= \frac{1}{2}''$ on the object, $\frac{1}{8}'' = \frac{1}{4}''$, $\frac{1}{16}'' = \frac{1}{8}''$, etc.

For 3 inches to the foot, or $\frac{1}{4}$ size, 1 inch is represented by $\frac{1}{4}$ inch, and the subdivisions would be read thus: $\frac{1}{8}'' = \frac{1}{2}''$, $\frac{1}{16}'' = \frac{1}{4}''$, etc.

For $1\frac{1}{2}$ inches to the foot, or $\frac{1}{8}$ size, 1 inch is represented by $\frac{1}{8}$ inch, and the subdivisions are read thus: $\frac{1}{16}'' = \frac{1}{2}''$, $\frac{1}{32}'' = \frac{1}{4}''$, etc.

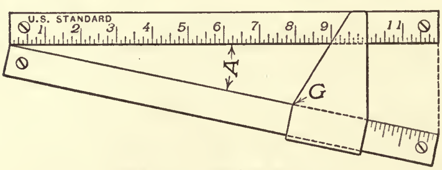


Fig. 66.—Shrink Rule.

Sometimes an unusual scale is required, such as a **shrink rule for pattern makers.** To construct such a scale or rule, secure a standard twelve-inch rule and the blank rule that is to *represent* twelve inches on the new scale, as shown in Fig. 66. Make a ruling gauge, G, of thin sheet metal, with a guide flange turned down to bear against the outer edge of the blank. Slide the gauge along the blank and mark the graduations as the upper edge of the gauge coincides with the standard graduations.

**61. Choice of Scale in Drawing.** The best scales to use in making shop drawings are full size, half size, three inches to the foot, and one and one-half inches to the foot. The one used depends on the relative proportion of the size of the object and the size of the drawing desired. The scale of a drawing should not be so small that all dimensions and information cannot be clearly given. After the scale of a drawing has been decided upon, it must be rigidly adhered to throughout the construction of the views of a *single* part, but different parts may be drawn to different scales if there is any advantage to be gained in so doing.

**To illustrate how to determine the largest scale** that can be used for any particular drawing, suppose a drawing of the Lathe Leg (see page 122, Fig. 84) is to be made on a standard 12″ × 18″ sheet and is to consist of three views. A rough sketch as shown in Fig. 67 is made to some scale, and the size of the rectangle required to inclose the necessary views, when grouped in their proper relation to one another, is determined. This rectangle measures 42″ by 36″, and therefore if drawn one-half size it would be ($\frac{1}{2}$ of 42 = 21 by $\frac{1}{2}$ of 36 = 18) 21″ by 18″, and could not be drawn on the sheet which has a working space of only 16″ by 11″ (see page 106, Fig. 73). The largest scale possible, if the part is represented vertically on the sheet, will next be determined. Dividing 11 by 42″ gives approximately 0.26, and, referring to § 60, page 91, it is seen that the nearest *desirable* scale corresponding to 0.26 is $\frac{1}{4}$ size, or 3″ = 1 foot. This scale is therefore adopted, the drawing is arranged vertically on the sheet, and the balance of the space is available for other purposes.

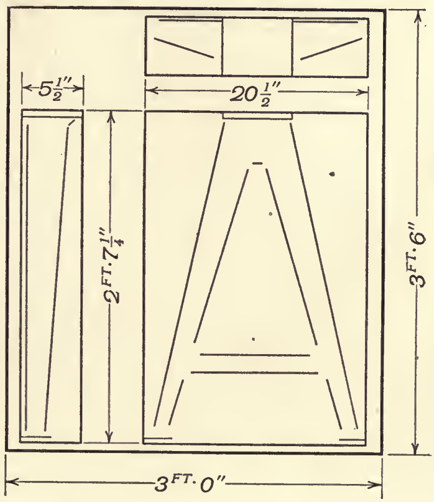



Fig. 67. — Determining the Scale.

**When it is desired to represent a number of parts on a single sheet of fixed size,** each part should be handled as described above. After the scale has been decided on, the rectangles should be laid out very lightly on the sheet and arranged symmetrically *before* beginning the actual work of drawing, care being taken that *views are separated by sufficient space to properly allow for all dimensions.*

**62. Dimensioning Working Drawings.** The dimensions are the *most important* feature of the drawing, and so far as the workman is concerned the drawing serves only to show where the dimensions apply.

**To be of use the dimensioning must be done systematically,** and with the needs of those who will use the drawing constantly in mind. The *proper dimensions* are determined by considering the processes the material must undergo in the making of the part. In considering such processes the methods and available tools of the different departments of the shop through which the part will pass to reach the finished state must be kept in mind, and those dimensions given which the workmen will require.

**A drawing has been completely dimensioned** when it has all information necessary for getting out stock, making patterns and cores, machining, erecting, etc., the information being in such shape that no workman will be required to make a computation to get a necessary dimension, or to seek information of any kind beyond that recorded on the drawing or specifications.

The ability to dimension a drawing *satisfactorily* comes from experience and a thorough knowledge of the shop processes used in making each part. A few general requirements, however, can be given, and these should be carefully studied by the beginner before attempting to dimension a drawing.

**The dimensions on a drawing must be accurate, useful, clear, and complete.** If the dimensioning is inaccurate, no degree of perfection otherwise can redeem the drawing; it is worse than useless, for when the part the drawing represents is made it will be wrong, and the labor and, depending on the magnitude of the error, material will be totally or partially lost.

To lessen chances of making an error, **check computed dimensions** by scaling and scaled dimensions by computation, and if the two do not agree determine which is wrong. Always bear in mind that the dimension figures on a drawing represent the *actual* measurements on the object, and not the measurements on the drawing, so that *in case the "scaled" dimensions and the calculated dimensions fail to agree, the workman will assume that the figures are correct and make the part accordingly.*

**If a dimension is not to scale**, however, indicate the fact in some manner. This is sometimes done by underlining these figures which are not to scale.

**Place arrowheads** so no mistake can be made as to where the dimension applies. There must never be the least doubt in this regard, and *the dimension line must always be drawn far enough from other lines to avoid confusion.* The **dimension numbers** must be perfectly plain and placed as near the center of the dimension line as practicable, and they should read from the bottom or right-hand side of the drawing. *Never place dimension numbers on center lines* and never draw a line of any kind through such numbers.

**The numbers expressing a dimension** should be so selected that they can be *conveniently* used by the workmen — feet, inches, fractions, or decimals, as the case may be. Because of the general use made of the two-foot rule, dimension figures *up to* 24 *inches* should be expressed in inches; *from and including* 24 *inches* they should be expressed in feet and inches.

To avoid chance of mistakes **the abbreviation Ft.** should be written after the number of feet, and the *double* accent mark used to indicate inches. The numbers representing feet and representing inches are separated by *a dash* one-eighth of an inch long, thus 18 Ft. – 7″.

In some classes of work, such as locomotive work, dimensions are often given in inches only.

*Judgment must be used in the degree of refinement called for by the dimension.* **Rough castings,** even if small, cannot be measured to one-sixteenth of an inch accurately, and therefore it is useless to give a precise measurement between a finished surface and the end of a casting, while in the case of such work as a **force fit**

the dimension may be given to several decimal places, the variation allowable from the given figure being indicated in the following manner: $3.128\,^{+0.005}_{-0.005}$,— meaning that a variation of 0.005 above or below 3.128 is permissible.

Where dimensions on the drawing indicate the final dimensions of the part when complete, no allowances are made by the draftsman for shrinkage of castings, finishing, etc., as this is usually taken care of in the shop.

The **over-all dimensions** are so frequently useful in estimating, getting out stock, etc., that they should always be given. Place over-all dimensions *outside* of subdimensions, and in cases where dimensions are grouped in parallel lines the shortest dimension should be inside, the longest outside, and all others so arranged that dimension lines do not cross.

Always check over-all dimensions carefully to see that they agree with the sum of the dimensions which go to make them up. Do not rely upon scaling alone in adding up a line of subdimensions to determine an **over-all dimension,** because if the drawing is slightly out of scale the result will be wrong.

**If a subdivided dimension is between a finished surface and the end of a casting,** the last subdivided dimension should be omitted and an over-all dimension given.

The inexperienced draftsman will often give dimensions on a drawing which it is impossible for the workman to use in making the part. For this reason the dimensions placed on a drawing in a haphazard way, even if accurate, are very often worse than useless. All measurements possible should be from center lines that are *convenient* for the workman to locate on the object or from finished surfaces. **Give the distance between centers** of important parts, and if the object is symmetrical, give the distance of these centers from the main center line.

**Do not repeat dimensions unnecessarily** as this increases the possibility of error. Where it is necessary to repeat dimensions an error is more likely to be discovered if the dimensions are placed in corresponding positions on the different views.

**Similar parts** should be similarly dimensioned and dimensions which are related should be kept near one another.

**Do not crowd all dimensions on a single view,** but distribute them to avoid confusion.

Dimensions should not be crowded into limits inadequate to receive them, and if the space is too small for the figures, they may be placed outside, with or without a **leader** — that is, a line drawn to indicate where a note or dimension applies (see Fig. 88, page 125).

**If the space between reference lines is too small** to receive well-formed arrowheads, the arrowheads may be reversed and placed outside of the space to be dimensioned, see Fig. 82, page 118. **When a dimension falls on a sectioned area,** the section lining is omitted at the place where the dimension numbers are given.

Where a complete **circle** is shown on the drawing, such as a bored hole or turned piece, give the diameter. **Cored holes** are dimensioned by giving the diameter and stating that they are to be cored; thus, **½″ core.** **Fillets** and rounded corners are given by their radii. In giving the radius of a circle, **R** or **Rad.** is written after the dimension figures, and an arrowhead is placed at the arc but not at the center. **Threaded pieces** and **tapped holes** are dimensioned by giving the diameter and number of threads per inch; thus, **½″–13 thd.,** or **½″–13 tap.**

**Dimensions of angles** should be given in degrees and minutes or by coördinates from a reference line, depending on how they are to be used. **Tapers** should be stated per foot of length and in the case of conical surfaces should be given as taper on the diameter.

**63. Notes on a Drawing.** Lengthy notes should not be required on a drawing to make it clear, but there are times when the art of drawing fails in its purpose and a *brief note carefully worded* saves the workman much uncertainty. In such cases an explicit note of instruction is not only permissible but absolutely essential. When possible, notes should be placed in horizontal lines and very close to the part to which they refer, in order that they may be quickly read and easily understood. All notes should consist of short, explicit and concise sentences, should leave no doubt as to their exact meaning, and should read from the bottom or the right-hand side of the drawing.

State all special directions and instructions pertaining to making, painting, shipping, erecting, etc., in properly worded notes. No lettering of notes should be attempted on the drawing without first ruling very light guide lines to insure an even height and slope of letters. Guide lines should be drawn very lightly and erased after the note is completed. Retrace any letters made dim by erasing. **All notes on drawings in this course** must be lettered in the standard Gothic capitals, unless otherwise stated. The letters must be $\frac{3}{32}''$ high. **Figures in a note** should be made slightly higher than the letters, say, $\frac{1}{8}''$ high.

**64. Indicating the Finish of Surfaces.** The surfaces of a casting or forging are spoken of as " rough " when in the condition in which they leave the foundry or mill, and "finished" when the piece has been subjected to some tool operation. Some of the **shop operations for finishing surfaces** with cutting tools are turning, planing, milling, grinding, reaming, filing, scraping, and chipping; besides these processes, surfaces are often polished, grained, matted, etc., to produce artistic effects. It is necessary to indicate on the drawing the kind of finish a surface is to be given, so that the proper department will attend to it, and also in order that the pattern maker or blacksmith will allow for the material *that must be removed* in producing this finish. The usual method of indicating a finish made by machining is to place the letter *f* across the *edge view* of the surface to be so finished. (See Fig. 68.) If it is to be other than the ordinary machine finish, a note to that effect should be added and a leader run from the note to the finish mark. If all the surface of a part is to be finished the several "*f*" marks are omitted and the note "*f ALL OVER*" is printed near the part number. As shop methods and processes are continually being changed in an effort to increase production and reduce the cost of manufacture the drawing should *not* specify the process by which the finish is to be obtained.

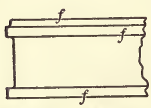


**Fig. 68.—Method of indicating Ordinary "Finish" on a Surface.**

**65. Use of Record Forms and Titles.** A complete record must be kept of every drawing, and most of this record should

be on the drawing itself in a particular and invariable space reserved for that purpose. That portion of the record which is placed on the drawing should be systematically tabulated according to a fixed form and should embrace at least the following items:

(1) *An appropriate title which will adequately describe the contents of the drawing.*

(2) *The name and address of the firm for which the drawing is made.*

(3) *The title and names or initials of those who are responsible for the finished drawing; this includes at least the checker and the approving engineer.*

(4) *The drawing number and a "part number" where necessary.*

(5) *A record of all changes made in the drawing to adjust it to meet conditions other than those for which it was originally intended.*

(6) *The date the drawing is officially adopted.*

(7) *The size of the drawing should be indicated in some manner so that it can be properly and systematically filed.*

Besides the above information some companies insist that the drawing bear the name and initial of all those responsible for it in any way. If this burdens the drawing with information useful in the drawing department only, the complete history of the drawing can be recorded on cards or in a special book reserved for that purpose. Also the machine or apparatus for which a part is usually *first designed* is recorded and some scheme is adopted such that if a part is used on several different machines the fact is recorded in such a manner that unnecessary duplication of patterns or uncertainty as to the number of pieces to be kept in stock is avoided.

It is very common practice to indicate the "scale" to which the parts represented on a drawing have been made, but the value of this practice is questionable, as there is a rule almost universally applied that "the workman must not *scale* a drawing to obtain a dimension." Also during the life of a drawing it frequently happens that dimensions are changed, but the drawing is not "kept to scale"; and for these reasons the "scale" on a drawing might be a temptation to break the above rule and in addition be misleading.

In practice many different systems are used to keep a **record of changes on a drawing,** the purpose being to have a history of progress made, and to be able to furnish repair parts for machines in service. There are several features to be taken care of in this connection but it is not within the scope of this book to go beyond pointing out the necessity of keeping a thoroughly reliable history of changes made during the life of a drawing.

**66. The Title-form on a Drawing.** The best location for a title-form is the lower right-hand corner of the sheet. This information so placed makes it easy to handle and file the drawing and particularly tracings.

There is no accepted standard for the outline and dimensions of a title-form, or the information recorded, but each individual establishment *evolves* one that is suited to its own use. Care should be taken in the final selection of a title-form as it is a very important item in a drawing room system.

The title-form shown in Fig. 69 represents a general average, and will be used in this work on all *mechanical* drawings of the

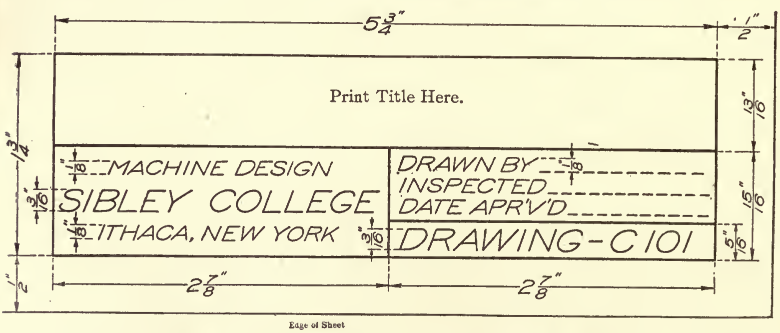



**Fig. 69.— Title-form to be used in this Work.**

12″ × 18″ size. This title-form, while especially applied to this work, follows closely the one now used successfully by several large manufacturing concerns.

All the **lettering in the title-form** is the Capital Slant Gothic style. By using the method described on page 69, § 49, the lettering in the title can be more satisfactorily arranged by the beginner.

The lettering of the title (or name of the drawing) is $\frac{3}{16}''$ high, and is located "centrally" in the space provided for that purpose which is $1\frac{3}{16}'' \times 5\frac{3}{4}''$.

All other lettering in the title-form is $\frac{1}{8}''$ high except the words *DRAWING* and *SIBLEY COLLEGE* (or whatever the name of the institution), which are $\frac{3}{16}''$ high.

The space between all lines of lettering in the title-form is $\frac{1}{16}''$ on the right-hand side and $\frac{1}{8}''$ on the left-hand side.

**67. Bill of Material.** A bill of material should be placed on every *detail* drawing to give the information required to make up the orders for the pattern shop, foundry, machine and forge

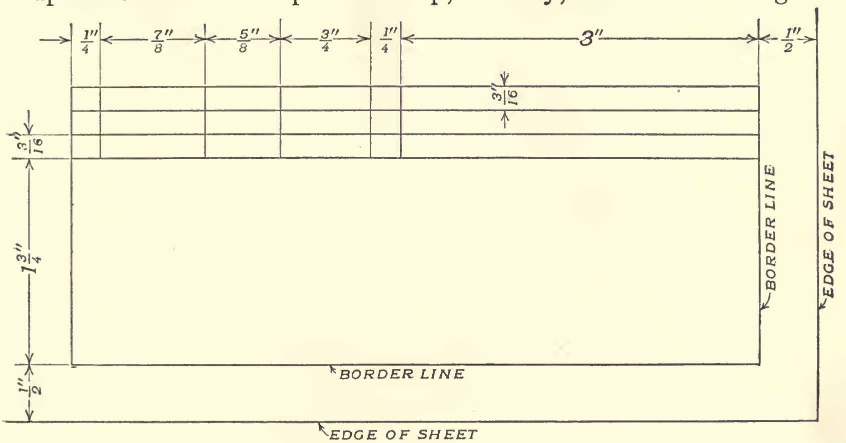



Fig. 70. — Bill of Material Form used in this Work.

shops; to get out machine lists, figure stock, cost, etc. The form for tabulating this data varies with different companies, as does also the place it occupies on the drawing. Fig. 70 shows a form for the bill of material that has proven entirely satisfactory under severe conditions and will be adopted for this work. In Fig. 70 the space $1\frac{3}{4}'' \times 5\frac{3}{4}''$ directly in the corner is reserved for the title-form (see page 100, § 66). Unless otherwise stated, locate the bill of material form just above the title-form, and provide at least as many $\frac{3}{16}''$ spaces as there are parts detailed and standard parts *called* for on the drawing. In practice extra $\frac{3}{16}''$ spaces are drawn to provide for future addition of parts.

All **lettering in the bill of material** is $\frac{3}{32}''$ high, is of the slant Gothic style, and is preferably all capitals.

**The first column** on the left contains the *number of pieces required* to make one complete machine (or structure) — in this case one lathe. **The second column** contains information as to the *material* of which the part is to be made. **The third column** is for *cross reference* and refers to patterns, other drawings, punches, dies, etc., and conveys some special information or instruction which is required to make the data in column four complete. Thus, if the bill of material on one drawing called for a piece, say, a washer, exactly the same as had been previously detailed on *another* drawing for a different machine, then column three would contain the word "punching," which explains how the part is made, and in column four would be written, "C–171," which would be the size and number of the drawing on which the washer is detailed. Should a part require the use of a pattern which has already been made for another machine, that fact could be recorded by writing in column three the abbreviation "Patt." for pattern, and the number of the pattern would be printed in column four. **The fourth column** contains *pattern numbers* (see page 104, § 70) when the part is a casting, punch and die numbers when the part is a punching, etc., and for other classes of work may be used as indicated above. **The fifth column** contains the *part numbers*. See page 104, § 69. **The sixth column** contains the name of the part and any other information thought necessary to identify the part.

This particular form of a bill of material has distinctive and valuable features which should be understood. It is so laid out that the *part numbers*, *pattern letters*, *etc.*, *read from the bottom upward;* this is done in order that a new part number may be added at any time. Also it is often found necessary to make a machine differing very little from one already detailed, and additional columns, each of which is exactly the same width as column one (see page 119, Fig. 83), can be added to the left of column one and new groups made. To illustrate, suppose a firm manufacturing the speed lathe should receive an order for a lathe of the *same general design* as the standard machine but to have a bed six inches longer. All that is necessary under

this system is to make out a new list *to the left of column one* and call it group two; schedule all parts in this group as in group one except the bed; add another part number to the top of the bill of material, and schedule the longer bed. Then add a note near the drawing of the original bed stating that for group 2 the bed is to be a certain length, and the drawings would be ready to go through the shop on the new order.

Wherever possible, parts which fit together on the complete machine should be recorded in the bill of material as consecutive items, as this simplifies checking and erecting. For example, if two castings fit together and are given the part numbers 1 and 2, the bolts or screws for fastening them together should be number 3.

**When standard parts are required,** such as standard bolts, nuts, washers, screws, etc., they are *not* detailed on the drawing, but are given a part number, and this number is printed in the regular way close to the place where the part is to fit, and an arrow from the circle points to the *exact* place it is used. This part number is also printed in the bill of material.

**The name of the material is usually abbreviated in the bill of material,** some of the more common abbreviations being: Cast Iron, C.I.; Wrought Iron, W.I.; Malleable Iron, Mal.I.; Machine Steel, M.S.; Cold Rolled Steel, C.R.S.; Cast Steel, C.S.; Steel Forging, S. Forg.; Steel Tubing, S. Tube.; Brass, B.; Bronze, Bz.; Phosphor Bronze, Ph. Bz.; Copper, Cop.; Babbitt, Bbt.; Fiber, Fbr. Where it is necessary to use a material of an exact analysis or specification it is best to call for it by a number (see page 81, § 55).

**68. Numbering and Indicating the Size of Drawings.** In order to be easily classified, recorded, filed, and referred to, drawings should be given a number. There is no universally accepted system for numbering drawings, and the method followed by each particular firm depends largely on the magnitude and variety of its business.

It is also necessary to have some simple and effective means of indicating the size of a drawing, as those of different sizes are usually filed in different cases or drawers.

In order to secure uniformity, and also to save waste in cutting paper and tracing cloth, four standard sizes of drawings have been adopted in most commercial drawing rooms, and these sizes are indicated on the drawing by a capital letter used in connection with the number of the drawing. For instance, the sizes indicated by the letter might be as follows: The letter A to indicate a drawing 24″ × 36″; B, a drawing 18″ × 24″; C, a drawing 12″ × 18″; D, a drawing 9″ × 12″.

**In this course all exercises in mechanical drawing are worked on paper** 12″ × 18″, and consequently their size is indicated by the capital letter C, and the block of numbers reserved for this work begins with 101 and extends to 200. Thus drawing C–103 would be 12″ × 18″ in size, and the third consecutive *mechanical* drawing made in the course.

**69. Part Numbers on a Drawing.** In order to refer to any individual part (or element of a machine) in making up orders, tabulating bills of material, etc., *each* part detailed on a drawing is given a number to identify it. This identifying number is termed the "part number" (or reference number), and is printed near the views of the part and is inclosed in a circle. On a pencil drawing both number and circle are double lined, but these are drawn solid *when inked*. (See Fig. 71.) The circle should always be drawn after the number is formed and in such a position that the number appears "central" in the circle.

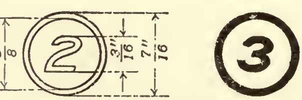


Fig. 71. — Layout of "Part Numbers" as used in this Work.

It sometimes happens that a single part will require more than one part number. As an example, take the washer detailed on drawing C–101. Two washers are required, of exactly the same *form and dimensions*, but are made of *different materials*. Therefore, in place of repeating the drawing of the washer, the one drawing is given two numbers, and the material of which each is made is called for at the proper place in the bill of material.

**70. Recording Patterns on a Drawing.** When a pattern is required in order to produce a part, the pattern should be given

a number so that it can be listed, identified and referred to. This number is usually assigned in the drawing room and is recorded in the bill of materials. This will be explained more fully later. When practical these numbers are fastened to the pattern in raised figures and letters, and therefore appear on the casting. By this means a broken or obsolete part of a machine may be replaced by simply ordering the part by its number from the manufacturers.

The method to be followed in this course for marking patterns will be to give to them the same number as the drawing on which the part is *first* detailed, and then add a capital letter to identify the patterns required by the different parts detailed on a single sheet. **The pattern letters on each drawing begin with A** and continue through the alphabet in the order they are recorded in the bill of material. Thus, the first pattern required on drawing 158 would be marked "Patt. 158–A"; the second would be marked "Patt. 158–B," and so on through the alphabet as far as necessary. It often occurs that in a new machine some part requiring a pattern will be the same as the corresponding part of an old machine. In such cases the *old pattern number must be given on the new drawing*, and the old pattern used for the new machine. For example, suppose the fourth pattern required on drawing 136 could be used for the first pattern required by drawing 158. Instead of numbering the pattern 158–A, it would keep its old number (136–D) and would be recorded as 136–D on drawing 158. The lettering of the new patterns required on drawing 158 would not be affected by the fact that one or more old patterns are called for. In marking patterns, such letters as *I*, *O*, and *Q* should be avoided, as they are easily confused with numerals of similar outline.

**71. Time Keeping in Drawing.** In practice the draftsman is usually required to keep a record of the time devoted to each drawing. This record is usually kept in a time book or on cards, and is of value in computing drawing-room expenses, as well as useful in determining to some extent the value of the draftsman's services to the company.

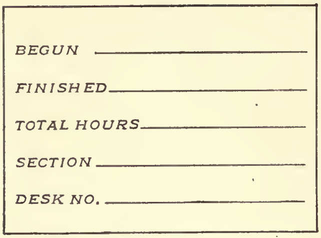



Fig. 72. — Time-keeping Form used in this Work.

In order to apply the principle of time-keeping in this course and yet avoid using the card system the form as shown in Fig. 72 will be used. This form is to be printed with the rubber stamp (provided for the purpose) just above the lower border line, and to the left of the title-form, unless another location is indicated.

**72. Border Lines.** Border lines are drawn parallel to and near the edges of the paper to form a frame for the drawing.

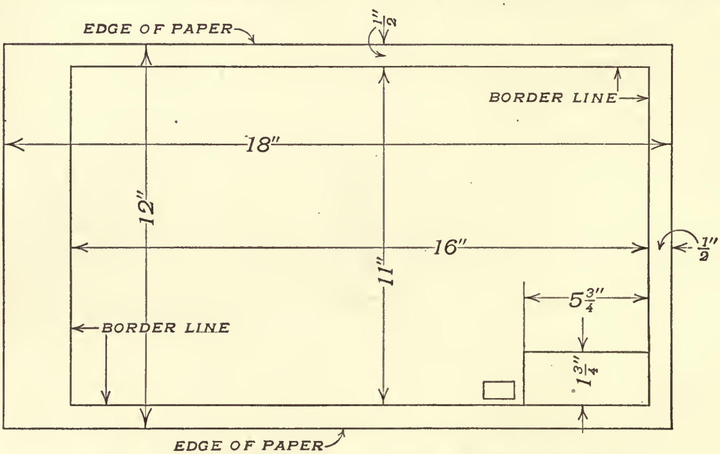



**Fig. 73.**—Layout of Standard Drawing as used in this Work.

Their principal object is to set off a margin, which gives the drawing a finished appearance, and to lessen the chances of poor results in trimming and blue printing. The border lines should be drawn very close, say, $\frac{1}{2}$ inch from the edge of the paper, as this margin represents so much waste space. *The border lines should be the first lines drawn on a pencil drawing*, in order to act as match lines to reset the drawing in case it has to be temporarily removed or shifted. *The border lines are drawn in last on an inked drawing* and should not be too heavy, say, not over $\frac{1}{32}''$ wide, the exact width depending somewhat on the size of the drawing.

Fig. 73 shows the layout of **border line to be used in this work.**

Having placed the paper "square" on the board (see this page, § 73), draw a very light horizontal line entirely across the paper, $\frac{1}{2}''$ from the top edge; make a mark on this line $\frac{1}{2}''$ from the right-hand edge of the paper, and then with the aid of the triangle, guided by the working edge of the T-square blade, draw in very lightly the right-hand vertical line through this point. Next, lay off the distance between the right and left hand border lines along the top border line, and by aid of the T-square and the triangle draw in the left-hand border line. On this line lay off the distance between the top and bottom border lines, and with the T-square draw in the bottom border line. *Any part of the lines extending beyond the corners must be erased*, and the whole border retraced and the lines made clear cut and of the desired weight. The wide margin on the left is to allow for binding the sheets of this course together. In practice, however, it is customary to have the same margin on all sides.

**73. To Fasten the Paper or Tracing Cloth to the Board.** The paper or cloth should be "square" with the board; it should lie perfectly flat and smooth, and only one drawing should be tacked

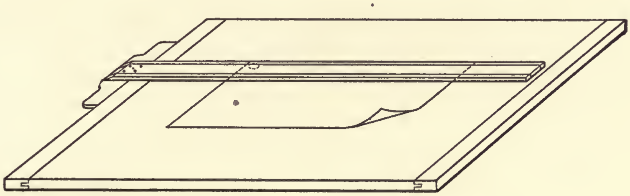


Fig. 74.— Placing a Drawing on the Board.

on the board at a time. Place the paper about midway between top and bottom, and rather close to the left-hand edge (i.e., working edge) of the drawing board and insert a thumb tack in the upper left-hand corner. Then, holding the T-square in its proper position with the left hand, manipulate the paper or cloth with the right hand until the upper edge of the paper and the working edge of the T-square are in line. (See Fig. 74.) Smooth the paper diagonally with the right hand from the upper left-hand to the lower right-hand corner and tack this

corner down. Next, smooth the paper from the center to each of the other two corners and tack them down. To securely fasten large sheets, it is usually necessary to use thumb tacks along the edges as well as at each corner of the sheet. All thumb tacks should be so placed that the outer edge of the head comes about even with the edge of the drawing paper or tracing cloth. Also the thumb-tack head must be pushed tight against the paper so that the head will offer the least obstruction to the triangles and T-square. It is often advisable in doing accurate work to temporarily remove a thumb tack if the head interferes with the free use of triangles or T-square, but in such cases the alignment of the drawing must not be disturbed.

Stretching or smoothing the paper or tracing-cloth with soiled or moist hands injures the drawing surface.

Unless stated to the contrary, *the drawing paper for this course should be tacked down with short dimensions parallel to the working edge of the drawing board.*

**74. To make a Pencil Drawing.** Good penciling is a requisite to good inking, and a drawing is seldom improved in inking if poorly done in pencil. The pencil must be kept well sharpened (see page 15, § 14), so that the lines drawn will be clear, sharp, and of the proper weight.

The direction in which *mechanically made* lines in either pencil or ink should be drawn is shown on page 21, Fig. 19. Vertical lines and all those lying in the angle AOC are ruled against the left-hand edge of the triangle and the lines in the angle COE are ruled against the right-hand edge.

Center lines should first be drawn as light continuous lines, and later be retraced in their proper construction, being left broken where necessary to avoid crossing a dimension figure. Such a break in a center line should be made about the middle of a long dash and should *not* immediately precede or follow a short dash of the line. If the center lines are drawn heavy at first they must be erased at the places where they would cross dimensions, and if not gone over again the ends next to where the erasing was done are ragged.

Do not complete each view separately, but, having one well along, commence the drawing of others. In this manner errors are more readily detected, and the drawing of each view becomes a check on the others. All the views, however, representing one part should be completed before starting to draw another part on the same sheet.

**In making drawings of spindles, shafts, and parts where most of the lines are at right angles to one another,** measure off the horizontal lengths along the center line, and through these points draw the vertical lines of the drawing *very lightly* and of *indefinite* length. On these vertical lines measure the diameters, and through these points draw in the horizontal lines. These may be put in full weight at once, since their limits are defined by the light vertical lines. Next, that portion of the light vertical line which is needed is drawn in heavy. All the lightly drawn horizontal lines which are to become dimension lines are next gone over (between the proper reference lines) and formed into the two short and one long dash construction. These lines should be made of the proper weight, and left properly broken for their dimension figures. When all of the dimension lines are on the drawing, put in the arrowheads and dimensions, then letter in the necessary notes. Do not print in the dimension numbers until the drawing is completed, as this insures greater accuracy. There should be a space of at least $\frac{3}{16}''$ between a note and any line of the drawing, including dimension lines and figures. In laying off dimensions, point them off directly from the scale (see page 30, Fig. 32), and do not transfer them from the scale to the drawing by use of the dividers.

Time is often gained and the work is usually more accurate if the drawing is systematically done. **A good method of procedure in making a pencil drawing is as follows:**

1. *Draw border lines.*
2. *Block out bill of material and title form.*
3. *Arrange the views* (see page 74, Figs. 50 and 51, also page 75, Fig. 52) *and draw main center lines.*
4. *Draw the main lines of the part, using very light continuous lines.*
5. *Complete all views of the part.*

6. *Put in dimensions and notes.*

7. *Retrace center lines, making them the proper weight and of the characteristic dot and dash construction.*

8. *Complete title and bill of material.*

**75. Inking Drawings.** Before beginning to ink, thoroughly clean the drawing, removing all dust, lint, particles of worn-off rubber, etc., and be exceedingly careful that the hands and instruments, especially the triangles and the T-square, are clean and free from dust, so that they will not soil the drawing.

Examine the points of the bow pen, compass, or ordinary pen before using them, to make sure that the nibs are clean, are of the same length, and come together evenly. **Always shake the ink bottle well before using the ink,** since, when the bottle stands undisturbed for some time, the coloring matter in the ink gradually settles to the bottom. Under such conditions the charge of ink carried by the pen will not be of the same density, but will be more highly colored at first, and as the thinner ink from above reaches the drawing surface the line will vary in color; that is, taking the case of black ink, it will vary from a jet black to a grayish black in appearance. When such lines are on tracings it is impossible to obtain satisfactory blue-prints. **After filling the instrument with ink,** test it on a separate piece of paper to see that the ink is flowing properly and that the width of the line is correct. **If the ink does not flow freely,** touch the point of the pen to the drawing board, the penwiper, or the end of the finger. If ink still does not flow, slightly dampen the finger and touch it to the point of the pen, or remove the dried ink with a slip of thin paper drawn between the nibs. (See Fig. 75.) As a last resort, thoroughly clean and refill the pen. *More unsatisfactory work results from the use of a dirty pen than from any other cause, hence the nibs of the pen should be cleaned each time a charge of ink has been exhausted, and under no circumstances should the pen be put away without having been first thoroughly cleaned.*

**Fig. 75. — Cleaning the Ruling Pen.**

**Before inking a line,** understand *what kind* of a line it is, that is, whether full or broken, the purpose of the line, and where it begins and ends. **Start inking at the top and left-hand side,** and work down and toward the right, for in this way the wet ink is not smeared with the hand, T-square, or triangles.

**In drawing a line,** hold the pen at the starting point *for an instant* until the ink begins to flow, and then move it along the pencil line at a uniform and moderate speed. On reaching the end of the line, *immediately* raise the pen from the drawing, otherwise the ink continues to flow and the line spreads at the end. If a good line is not produced at the first attempt, *do not push the pen backward over the line,* but go over it a second time in the proper direction, taking care not to widen the line in retracing. **If several lines meet** at a point, allow sufficient time for each line in turn to dry, and, if possible, ink from, and not toward, the point of intersection. Since it is difficult for a beginner to join two lines so that they appear smooth and continuous, *the pen should hold sufficient ink at the beginning to complete the line.* **Too much ink in the pen gives a heavier** line than is desired, and **too little ink** results in too light a line.

Blotting and faulty lines are two of the main sources of trouble in inking a drawing. **Blotting** may result from overloading the pen with ink; from allowing the ruling edge to come in contact with a line before it is dry; from lint, particles of worn-off rubber, or dust being caught on the point of the pen; from inclining the pen toward the ruling edge so that ink is drawn under the edge of the T-square or triangle; from getting ink on the outside of the nibs in filling the pen, or because of the nibs being nicked, corroded, or otherwise out of condition. **If a blot is made,** absorb the *surplus* ink by applying the corner of a blotter to the *top* of the ink globule. To lay the blotting paper directly on the blot tends to spread the ink and to injure the wet surface.

**Faulty lines** are usually of variable width or ragged along the edges. A line of variable width may result from changing the speed at which the pen is moved, thus causing a variable flow of ink; and from varying the pressure against the drawing or ruling edge, thus springing the blades and changing the dis-

tance between the nibs. The pen point may encounter lint, dust, or particles of worn-off rubber in its path, thus causing the ink to flow irregularly, or the pen may be too full or not sufficiently full of ink, thus varying the rate of ink flow.

**A ragged line** may result from the pen not being clean; the nibs being so dull that the edges of the line are broken; both nibs not touching the drawing at the same time, due either to the blades being of different length or because the pen is not held in a vertical plane parallel to the working edge.

*Always allow ink to become thoroughly dry before attempting to erase it.*

**Drawing ink should never be blotted** as this causes the lines to appear dim and blotting on a tracing destroys the opaque qualities of the line for printing. A very wide line should be "built up" of a series of narrower merging lines made by parallel strokes.

Do not place the ink bottle on the drawing board as ink may be accidentally spilled. The danger of overturning may be lessened by using an **ink bottle holder,** several styles of which are on the market. A circular piece of wood or a piece of drawing paper cut to receive the bottle and hold it securely, as shown in Fig. 76, is commonly used.

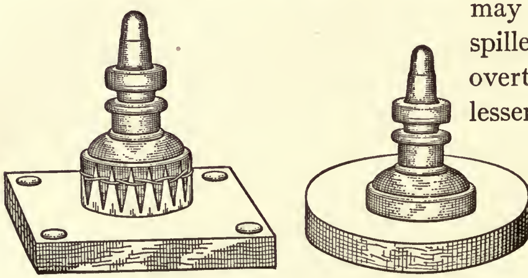


**Fig. 76. — Two Simple Designs of Ink Bottle Holders.**

The drawing, when not in use, should be kept covered with an extra piece of paper to protect it from the dust and dirt.

**Never begin inking a drawing until it has been completely finished in pencil;** and, in order to get the best results and to save time, *do the inking systematically.* Opinions differ as to the best order of inking the lines on a drawing, but on one point all are practically agreed, namely, that *curves tangent to or joining straight lines should be inked first,* and the straight lines drawn to the curves.

**In inking, a very good method of procedure is as follows:**

(1) *circles and arcs, beginning with the smallest;*

(2) *outlines, beginning with the lightest and inking all of one weight before taking up the next heavier;*

(3) *hidden surface lines;*

(4) *extension lines and dimension lines;*

(5) *arrowheads, dimensions and notes;*

(6) *cross-section lines;*

(7) *bill of material and title;*

(8) *border lines.*

**76. Checking Drawings.** The process of checking consists in making a thorough examination of every detail and feature of the drawing to detect any errors it may contain. The importance of efficient checking is realized when the ease with which an error can be corrected on a drawing is compared with the difficulties and expense that would result if the same changes had to be made on a pattern, casting, or forging. *Final checking should not be done by the same draftsman who made the drawing*, as one does not readily detect his own errors. In most drawing rooms there is an official "checker" whose duty it is to see that drawings are correct in every detail and who is responsible for the accuracy of drawings which bear the official mark to indicate they have been checked. The checker usually signs his initials and the date of checking in the title form of the drawing.

*The beginner should always check his own work thoroughly* in order to gain some knowledge of checking, as well as to detect any oversights or errors it may contain. *The checker must first inform himself of what is wanted*, and then by methodical steps examine the drawing to see if it completely fulfills all requirements. **A good method of procedure in checking is as follows:**

1. *See that a drawing of every part and of necessary assemblies has been made, and that enough views are correctly drawn to completely represent each part.*

2. *See that all scale dimensions agree with the dimension figures given on the drawing, and that where a series of sub-*

*dimensions make up an "over all" (total dimension) no error has been made.*

3. *See that related parts do not interfere; i.e., check each part with those parts to which it will be adjacent in the assembled machine, to see that corresponding dimensions agree, and that proper clearances have been allowed.*

4. *See that dimensions are given correctly, so that no computing or scaling will be necessary when working with the drawing, and that notes and figures are plain and in the position in which the reader is most likely to look for them.*

5. *See that no arrowheads are missing, and that all marks for feet and accents for inches are correct and none omitted.*

6. *Lay out to scale and on a separate sheet the path of motion for moving parts, and see that the proper clearances are maintained in all positions.*

7. *See that no center lines are missing, and that they are all correctly shown.*

8. *See that finished surfaces are properly indicated.*

9. *See that all stock material, such as screws, bolts, rivets, keys, etc., are as far as possible of standard size.*

10. *Check supplementary notes and all instructions and every feature of the bill of material and title.*

In addition to the above see that all the instructions given in Appendix A, page 175, are carried out with reference to exercises in this course.

77. **Tracing.** A tracing is an exact copy of a drawing, made by placing transparent cloth (see page 6, § 6) or paper (see page 6, § 5) over the drawing and tracing on this cloth or paper lines to correspond to those of the original drawing.

In commercial drafting rooms the tracing is the permanent record of the drawing and is used as a negative to produce additional copies of the drawing, usually by the blueprint process.

**To make a tracing,** stretch the cloth over the drawing to be traced until it is fairly taut and perfectly smooth and even. Place a thumb tack in each corner, and a sufficient number around the edges to hold it flat and well stretched. **Before beginning to ink,** sprinkle the surface of the cloth with powdered chalk,

and rub lightly with a soft, clean rag to overcome the effects of any oil that may be present; then brush off the chalk with a clean rag so that it will not pile up in front of the pen when inking.

Greater care is required to make a drawing on tracing cloth than on drawing paper, especially if the glazed side of the cloth is used. One very important precaution to be taken is to see that the pen is clean, sharp, and otherwise in good condition. The pen should carry less ink than when working on paper, as the ink has a greater tendency to spread. Take special care to draw the ink lines exactly over the pencil lines of the drawing being traced. Be very careful in inking **lines that meet or intersect,** since if the first line is not dry (ink dries slower on cloth than on paper) before the second is drawn, a blot will result at the point of meeting. **Work only on one part of the tracing** at a time, and whenever possible complete a view before leaving the drawing for any length of time, the reason for this being that moisture in the air affects the cloth, and may cause it to warp to such an extent that it will be difficult to complete the view later on. **When the cloth warps,** remove thumb tacks and readjust it to fit over the lines of the drawing as accurately as possible. **Moisture will destroy the surface** and transparency of tracing cloth, rendering it unfit for printing or drawing. For this reason avoid working on the cloth with damp hands. **A tracing may be cleaned** with a rag or sponge moistened with benzine or gasoline. **Never fold or crease tracing cloth.**

**The same systematic order given for inking a drawing should be followed in tracing.** See page 110, § 75.

**Erasures on a tracing** must be avoided as far as possible, but it is often necessary in practice to make complete changes of portions of a view, and for this reason *the beginner must learn to make erasures* without spoiling a tracing. After the erasure has been made, the smooth surface must be restored before again applying ink. To smooth the surface, rub the injured area with a soapstone pencil and polish with a cloth. See page 18, § 17.

*Never use a knife to scratch out lines* on tracing cloth, as this may cause permanent injury to the surface of the cloth. In drawing over an erased area, set the pen for a finer line than is

required and build the line up to the required width by making several strokes.

**78. Blueprints.** A tracing is used as a negative in reproducing copies of a drawing by the blueprint process. Such prints are termed "blueprints" because the reproduced drawing is in white lines on a blue background. The prints are usually made in a **printing frame,** which is a device for holding the tracing and the prepared paper flat and smooth against a glass front. The right side of the tracing (i.e., the side on which the drawing has been made) is placed next to the glass; the chemically prepared side of the paper is placed next to the tracing and the back of the frame fastened down. The frame is then placed so that the glass front is exposed for a short time (the exact time depending on sensitiveness of the blueprint paper and the intensity of the sunlight) to the light and preferably to the direct rays of the sun, after which the exposed blueprint paper is taken out and washed in clean water. This method of printing depends more or less upon weather conditions, and to overcome all uncertainty and avoid delays, printing machines which print by electric light are used by many manufacturers.

**Changes and alterations on blue prints** may be made by several methods. A solution of common soda and water, or quicklime and water, used as ink, will give a white line; but the best method is to use a white pencil for making new lines, and a blue pencil for striking out white lines.

## SET OF MECHANICAL DRAWING EXERCISES.

**79. Drawing C-101.** A mechanical detail drawing to full-size scale is to be made of the Lathe Spindle (see Fig. 77), the Key

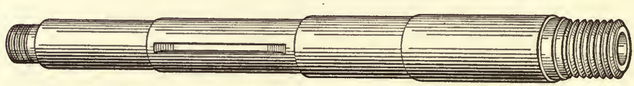


Fig. 77.—Perspective of Lathe Spindle.

(see Fig. 78), the Fiber and Steel Washers (see Fig. 79), and the Special Nut (see Fig. 80).

The purpose of the exercises on this drawing is to give practice in the use of the instruments required in making a *simple* me-

chanical drawing; to illustrate one method of arranging views, one method of dimensioning and lettering, the use of the title-form, the making up of a bill of material, and the use of the drawing-room system to be followed throughout this course.

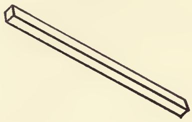


**Fig. 78. — Perspective of Key.**

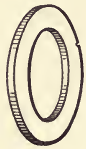


**Fig. 79. — Perspective of Fiber or Steel Washer.**

**Fig. 80. — Perspective of Special Nut.**

Study carefully the "Introductory," page 71, § 52, and "Detail Drawings," page 85, § 57, before attempting to draw. Also study the location and learn the purpose of each part on the assembled machine before drawing it. (See Frontispiece.) Fig. 82 shows

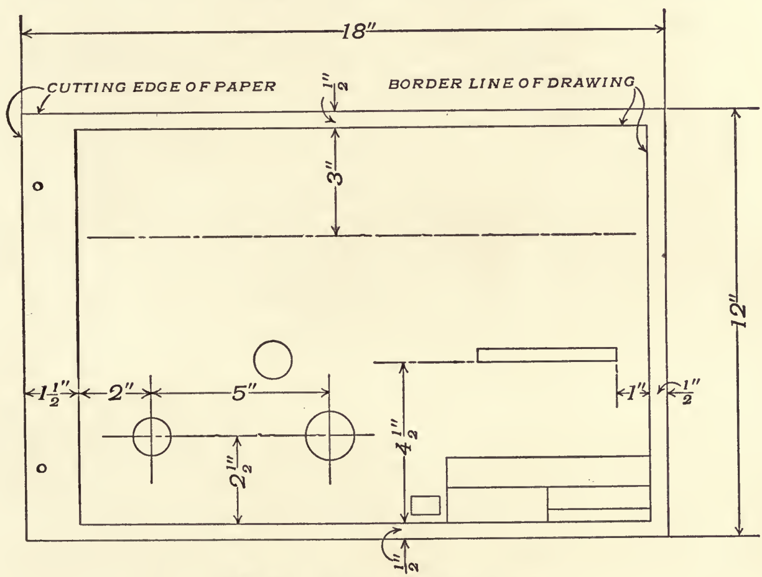



**Fig. 81. — Layout of Drawing C-101.**

the complete detail drawings of these parts, drawn to a reduced scale, and their location on the sheet is shown in Fig. 81. As it is essential to be able to arrange the views of a drawing symmetrically on the sheet, this is the only drawing in which the arrangement of views is given. It is also the only one for

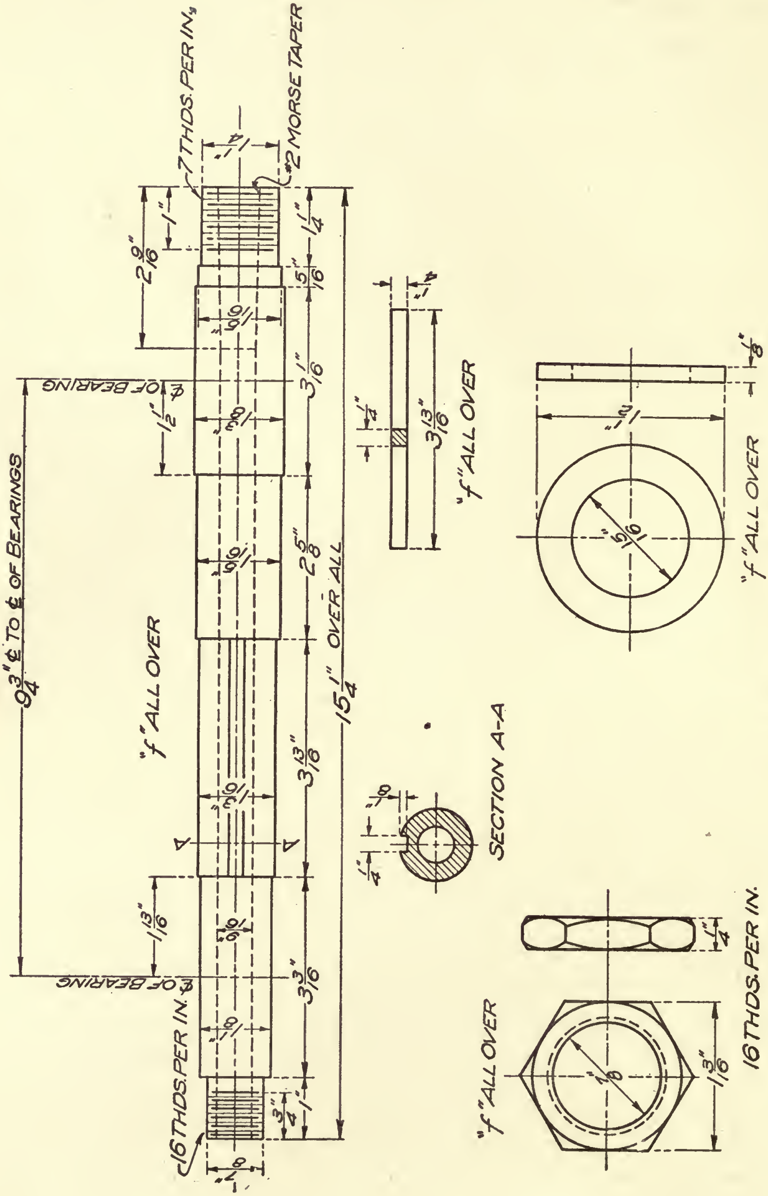



Fig. 82.—Details for Drawing C-101.

which the bill of material and title has been made out. (See Fig. 83.) These features should therefore be noted carefully.

Before starting on Drawing C–101 read, and prepare for examination, subjects taken up in paragraphs as follows:

Introductory, page 1, § 1, — Drawing Paper, page 4, § 3. — Drawing Boards, page 7, § 8. — Thumb Tacks, page 8, § 9. — T-squares, page 8, § 10. — Triangles, page 10, § 11. — Pencil Sharpener, page 14, § 13. — Lead Pencils, page 14, § 14. — Erasers and Erasures, page 16, § 15. — Erasing Shield, page 17, § 16. — Bow Pencils, page 27, § 25. — Scales, page 29, § 27. — Instrument Rag, page 33, § 30. — Introductory, page 34, § 31.

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| 1 | FBR. | | | 5 | WASHER |
| 1 | M.S. | | | 4 | WASHER |
| 2 | M.S. | | | 3 | SPECIAL NUT |
| 1 | C.R.S. | | | 2 | KEY |
| 1 | S.TUBE | | | 1 | SPINDLE |

SPEED LATHE DETAILS

| | |
|---|---|
| MACHINE DESIGN.<br>SIBLEY COLLEGE<br>ITHACA, NEW YORK | DRAWN BY__________<br>INSPECTED __________<br>DATE APR'V'D__________<br>DRAWING-C101 |

Fig. 83. — Complete Title and Bill of Material for Drawing C-101.

— Systematic Method in Lettering, page 44, § 36. — Designing Headings and Titles, page 69, § 49. — Conventional Lines, page 76, § 54. — Border Lines, page 106, § 72. — To Fasten the Paper or Tracing Cloth on the Drawing Board, page 107, § 73. — To Make a Pencil Drawing, page 108, § 74. — Checking Drawings, page 113, § 76.

Before making this drawing also be prepared to answer questions relating to mechanical construction as follows:[1] For what

[1] Questions of this nature should be asked with reference to each drawing to be made in order that the beginner will realize from the start that there is a relation existing between drawing, machine design and shop work.

reason is the spindle finished to so many different diameters? What is the purpose of the hole through the spindle, also of the Morse taper at the end? Why is the spindle made of steel? Of what use is the Key, the Special Nut, and the Washers?

*Specific Instructions.* (*a*) Tack down the sheet (see page 107, § 73). (*b*) Draw border line and title-form (see page 106, § 72, and page 100, § 66), and the bill of material form, shown in Fig. 70, page 101. (*c*) With the rubber stamp print in the blank form shown on page 106, Fig. 72, just above the lower border line and to the left of the title-form. (*d*) Write in with ink your *NAME* (and initials), and fill in the *DATE BEGUN*, etc. (*e*) The center line of the spindle detail should then be drawn, not in its finished form and weight, but as a very light continuous line (see page 78, § 54). Study § 74, page 108, before actually starting the drawing. After the outline of the view is completed, the center line can be made according to the conventional method, broken where necessary to allow for dimensions, and of the proper weight. Next, the outline of the spindle is drawn, in very light lines, after which the details of the view, also the section is drawn. The portion of any line extending beyond its proper limit must now be erased. When completed, all lines must be retraced and made the proper weight. (See page 76, § 54.) Next draw in the reference lines, being careful to always *leave a space* next to the surface from which the line is extended. If this is not done, it appears that the lines have been drawn *carelessly* and that they extend beyond their proper limit. Put in all dimension lines and arrowheads and write in all dimension figures and notes, always making them read from the bottom or right-hand side of the drawing. (*f*) The details of the key and the washer are to be next drawn. Since all details on this drawing are to be machine finished all over, the note "*f*" *ALL OVER* is printed near the part number of each detail. (*g*) Fill in the *DATE FINISHED, TOTAL ACTUAL HOURS* (required to complete the work), and the *TITLE* of the drawing. The Title of Drawing C–101 is *SPEED LATHE DETAILS.* (*h*) Check the drawing (see page 113, § 76), to see that all lines, dimensions, and notes are correct, that the bill of material is correct, and that the part numbers (see page 104, § 69)

have been put in. (*i*) Finally, have the drawing inspected, checked, and approved. (See page 175, Appendix A.)

**80. Tracing Drawing C-101.** After the pencil drawing C–101 has been approved it is to be traced.

Before starting to trace this drawing read, and prepare for examination, the subjects taken up in paragraphs as follows:

Tracing Cloth, page 6, § 6. — Erasers and Erasures, page 16, § 15. — Erasing Shield, page 17, § 16. — Soapstone, page 18, § 17. — Drawing Ink, page 18, § 18. — Ordinary Pens, page 18, § 19. — Penholders, page 20, § 20. — Ruling Pens, page 20, § 21. — Bow Pens, page 28, § 26. — To Fasten the Paper or Tracing Cloth on the Drawing Board, page 107, § 73. — Inking Drawings, page 110, § 75. — Tracing, page 114, § 77. — Freehand Inked Lines, page 136, § 96.

*Specific Instructions.* Tack down the drawing "square" on the board and fasten the tracing cloth so that it lies smooth and close to the drawing with the *glazed side up.* (See page 114, § 77.)

Chalk the tracing cloth and clean thoroughly with a soft rag.

Ink the tracing according to the instruction given in § 75, page 110.

Remember that inked lines are of three weights: those representing *visible* surfaces or outlines are drawn heavy; all construction lines, reference lines, center lines, dimension lines, section lines, etc., are drawn light; and lines representing *hidden* surfaces or parts are drawn medium, that is, one half the weight of visible lines and twice the weight of center lines and dimension lines.

After the tracing is inked, thoroughly examine the work to see that nothing has been omitted, correct any errors, and when the tracing has been checked, submit it for approval, then follow instructions in § 81 this page.

**81. Blueprint of Tracing C-101.** A blueprint is to be made of Tracing C–101 before it is submitted for final approval. The purpose of making the blueprint at this time is to give the beginner the benefit of this experience before making a second tracing. *Examine the print very carefully* to see if all

lines are white and clear, and in case some are not, examine the tracing to find the reason, and profit by this knowledge in making succeeding tracings. *All Blueprints must be trimmed and filed with the drawings and tracings.*

In connection with this exercise read, and prepare for examination on, paragraphs, as follows:

Tracing paper, page 6, § 5. — Blueprint Paper, page 6, § 7. — Drawing Ink, page 18, § 18. — Blueprints, page 116, § 78.

Having made a satisfactory blueprint, submit same for final approval.

*Any tracing spoiled by moisture in the process of blueprinting must be made over.*

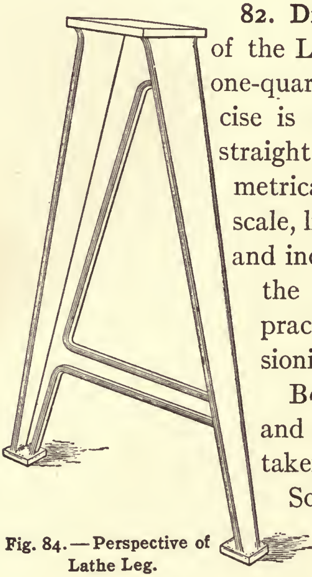


Fig. 84. — Perspective of Lathe Leg.

**82. Drawing C-102.** A mechanical drawing of the Lathe Leg (see Fig. 84) is to be made one-quarter size. The purpose of this exercise is to introduce the problem of joining straight lines to curves, arranging views symmetrically on the sheet, making a drawing to scale, listing patterns in the Bill of Material, and indicating finished surfaces; to illustrate the use of cross sections and to provide practice in drawing, lettering, and dimensioning. Fig. 85 shows the views, etc.

Before starting on Drawing C–102 read, and prepare for examination, the subjects taken up in paragraphs as follows:

Soapstone, page 18, § 17. — Compasses, page 23, § 22. — Dividers, page 26, § 23.—Bow Dividers, page 27, § 24.—The Study of Lettering, page 34, § 32. — Projection and Projected Views, page 73, § 53. — Choice of Scale in Drawing, page 93, § 61. — Title-form on a Drawing, page 100, § 66. — Bill of Material, page 101, § 67. — Numbering and Indicating the Size of Drawings, page 103, § 68. — Recording Patterns on a Drawing, page 104, § 70.

Before making this drawing also be prepared to answer questions as follows:

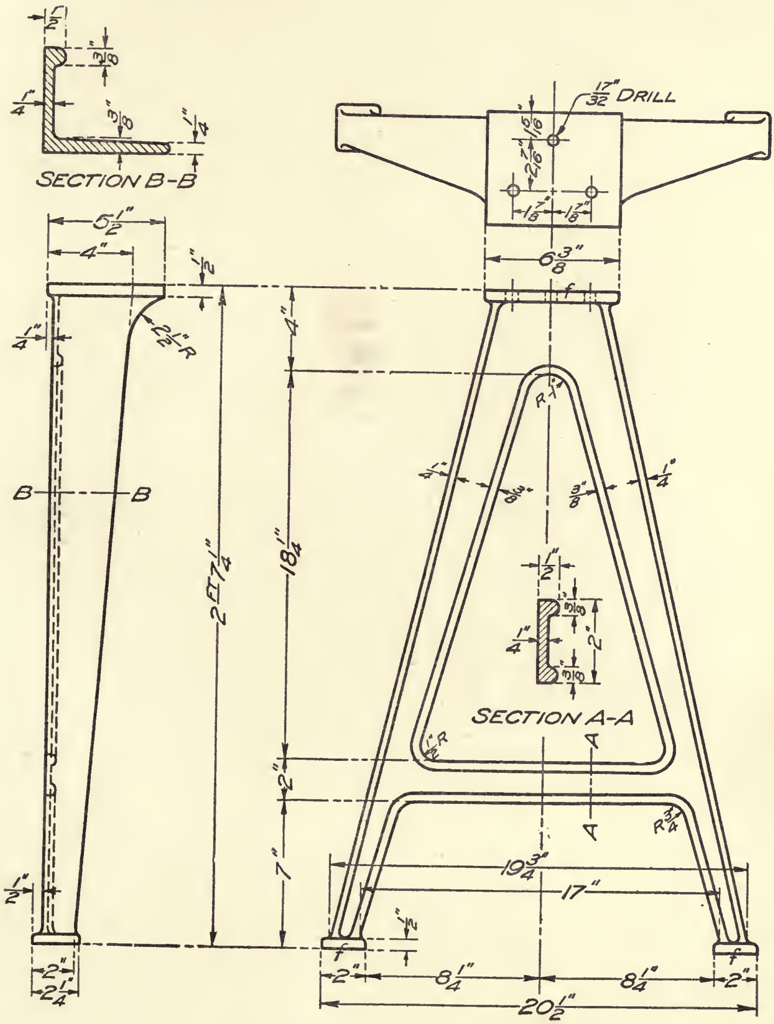



Fig. 85.—Details for Drawing C-102.

State the reason for finishing the surfaces as indicated. Explain exactly how the legs and bed are held together. What is the purpose of the three $\frac{17}{32}''$ drilled holes on the lathe bed? Explain the reason for selecting the cross section shown on the drawing.

*Specific Instructions.* (*a*) Tack down sheet. (*b*) Draw border line and title-form. (*c*) Stamp printed form just above lower border line and to left of title-form. (*d*) Write, with ink, *NAME* (and initials), fill in *DATE BEGUN*, etc. (*e*) Arrange views. See page 83, § 56, on Number and Arrangement of Views. (*f*) Proceed to make the drawing. See page 85, § 57, on Detail Drawing. (*g*) Fill in *TITLE*, *BILL OF MATERIAL*, *DATE FINISHED*, and *TOTAL ACTUAL HOURS*. The title of Drawing C–102 is *SPEED LATHE DETAILS*. (*h*) Check drawing, and submit for final approval. (See page 175, Appendix A.)

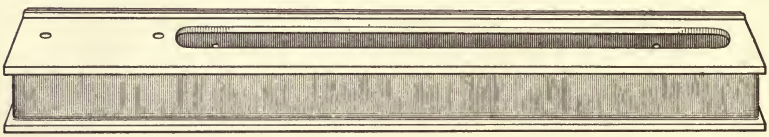


**Fig. 86. — Perspective of Lathe Bed.**

83. **Drawing C–103.** A mechanical detail drawing (see Fig. 88) is to be made of the Lathe Bed (see Fig. 86) and the Bracket for the shelf (see Fig. 87), also the Standard Parts belonging to the above parts are to be listed in the Bill of Material. Following is a complete list of parts which are to be called for in the Bill of Material:

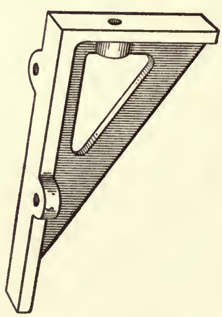


**Fig. 87. — Perspective of Shelf Bracket.**

Part #1 — Bed.

Part #2 — $\frac{1}{2}'' \times 1\frac{1}{2}''$ Square-head Cap Screw.

Part #3 — $\frac{1}{2}'' \times 1''$ Square-head Cap Screw.

Part #4 — Bracket for shelf.

Part #5 — $\frac{3}{8}'' \times 1\frac{1}{2}''$ Square-head Cap Screw.

Before starting this exercise read and prepare for examination on paragraphs as follows:

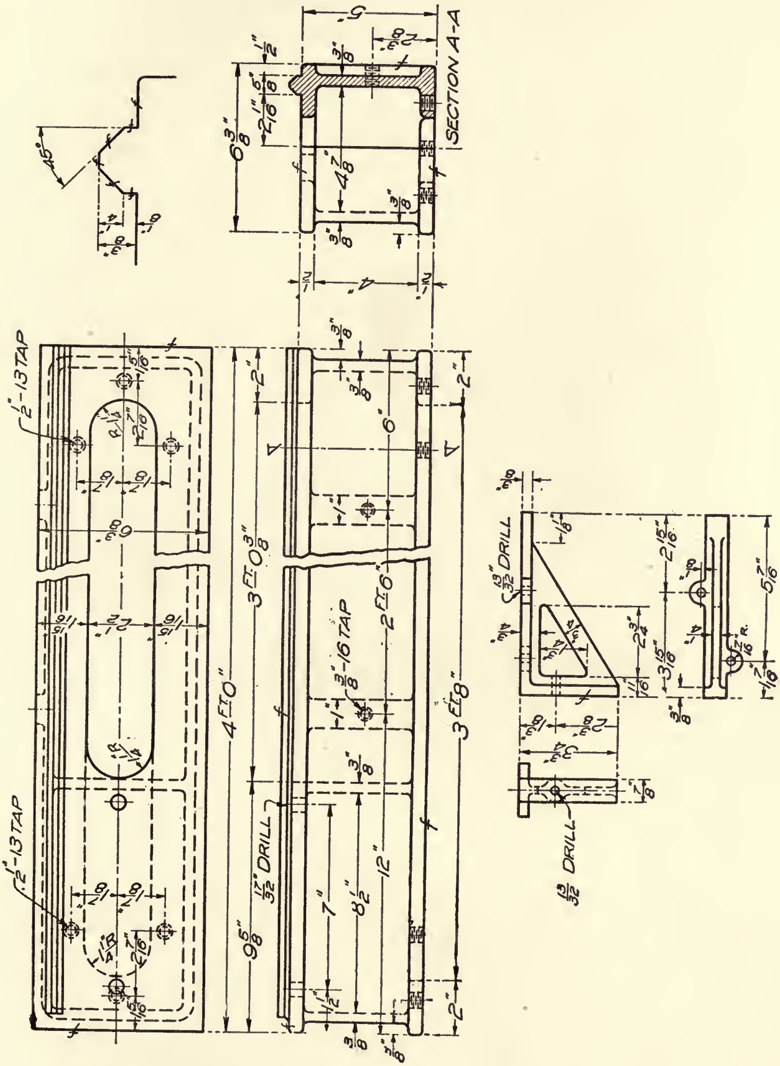



Fig. 88. — Details for Drawing C-103.

Introductory, page 71, § 52. — Conventional Lines, page 76, § 54. — Sectioning and Sectional Views, page 79, § 55. — Number and Arrangement of Views, page 83, § 56. — Detail Drawings, page 85, § 57. — Indicating the Finish of Surfaces, page 98, § 64. — Part Numbers on a Drawing, page 104, § 69.

Determine the number of each of these parts required, assign pattern numbers as necessary, etc.

The drawing is to be made to a scale of 4″ = 1 ft., and the title of the drawing will be *SPEED LATHE DETAILS.* No drawing is made of the *standard* parts (see page 103, § 67), but their reference numbers must be properly shown on the drawing from which a "leader" must be run to the exact place that the standard part is used on the part detailed.

*Follow specific instructions given for preceding drawings*, in so far as they apply to this drawing.

**84. Drawing C-104.** This drawing represents Bolts, Nuts and Screws, and is intended to introduce the method of proportioning parts by *empirical* formulas, i.e., formulas which have not been "derived" by purely theoretical consideration; also it is intended to teach the relative proportions (or dimensions) of U. S. (United States) Standard Bolts and Nuts.

This drawing is further intended to teach the relative proportions of the ordinary forms of screw heads in common use, the conventional method of representing screw threads and the method of calling for all such parts in a Bill of Material.

Before taking up this exercise read and be prepared for examination on paragraphs as follows:

Slope of Letters, page 36, § 33. — Conventional Methods, page 87, § 59.

It is coming to be more and more the common practice in the United States to use the U. S. *form* of thread, whether the piece threaded be a bolt, nut, screw or rod.

In the case of screws the manufacturers of the United States are gradually adopting the A. S. M. E. (American Society of Mechanical Engineers) standard.

Ordinarily none of these "standard" parts need be drawn out, but the exercises on this drawing will be very valuable to

the beginner because they will associate in the mind the *form* and *proportion*, the *number of threads* per inch and the method of calling for such parts in the Bill of Material.

*Specific Instructions.* Ideas as to this drawing can be gained by reference to Fig. 89, page 128. Having drawn the border line and the title-form, lay out and fill in the Bill of Material, the items being given below. The items in the Bill of Material can be abbreviated, but, owing to the limited space, it is even then necessary to compress the lettering which should be blocked out in very light lines before being printed in final form. Care must be taken, however, to correctly space letters and words.

The following items are to appear in the Bill of Material:

Part #1 — $\frac{1}{2}''$ × 6″ Square-head Bolt, Nut, Check Nut.
Part #2 — $\frac{1}{2}''$ × 6″ Hexagon-head Bolt, Nut, Check Nut.
Part #3 — $\frac{3}{4}''$ × $2\frac{1}{2}''$ Hexagon-head Cap Screw.
Part #4 — $\frac{3}{4}''$ × 2″ Fillister-head Cap Screw.
Part #5 — $\frac{5}{8}''$ × 2″ Round-head Cap Screw.
Part #6 — $\frac{1}{2}''$ × $1\frac{1}{2}''$ Flat-head Cap Screw.
Part #7 — $\frac{1}{2}''$ × $1\frac{1}{2}''$ Set Screw.
Part #8 — $\frac{3}{8}''$ × 1″ Headless Set Screw.

The following Table of Threads is to be placed *exactly* above, and $\frac{1}{2}''$ from the Bill of Material.

| Diam. of Bolt.. | $\frac{1}{4}''$ | $\frac{5}{16}''$ | $\frac{3}{8}''$ | $\frac{7}{16}''$ | $\frac{1}{2}''$ | $\frac{9}{16}''$ | $\frac{5}{8}''$ | $\frac{3}{4}''$ | $\frac{7}{8}''$ | 1″ | $1\frac{1}{4}''$ | $1\frac{1}{2}''$ | $1\frac{3}{4}''$ | 2″ | $2\frac{1}{2}''$ | 3″ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Threads per inch | 20 | 18 | 16 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | $4\frac{1}{2}$ | 4 | $3\frac{1}{2}$ |

The title of this drawing is *BOLTS, NUTS, AND SCREWS.*

The next step is to make substitutions in the formulas and work out the dimensions of the bolts, nuts, and screws. These computations must be *neatly inked on standard computation paper*, and the sheets attached with paper fasteners to the drawing when it is handed in.

As an illustration of how the computations are to be arranged, Item No. 7 is worked out as follows:

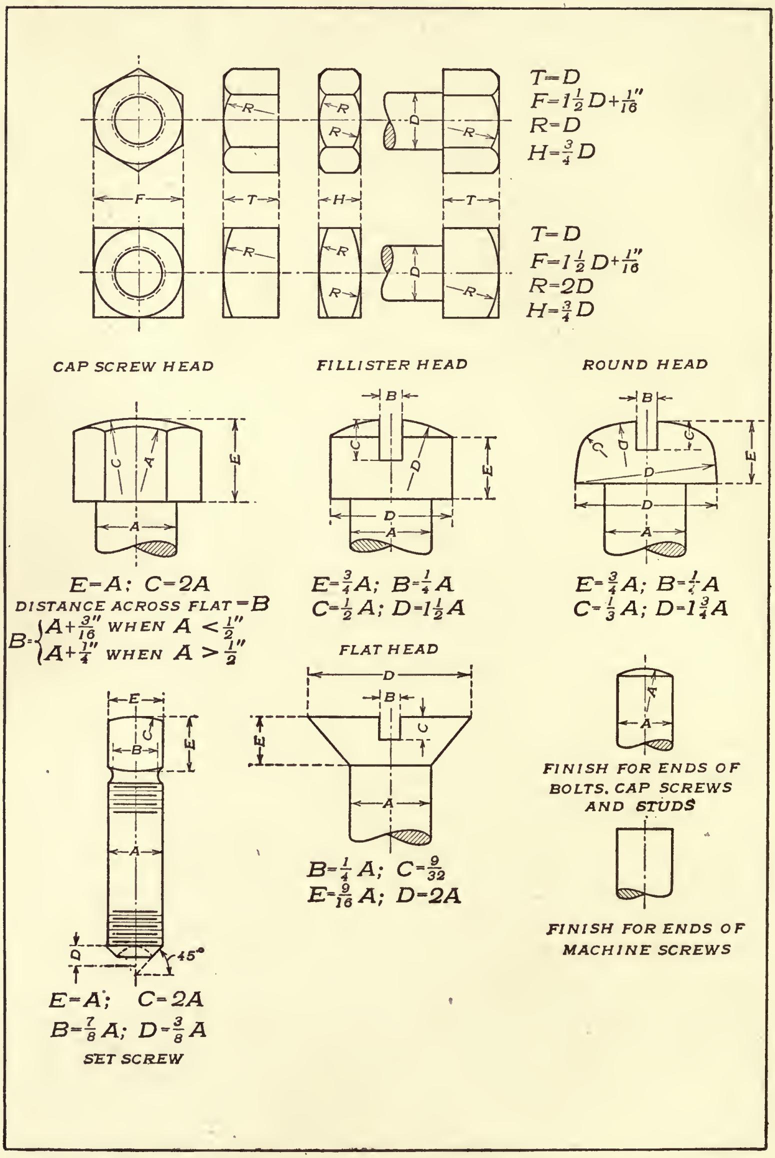



Fig. 89. — "Standard" Proportions of Ordinary Nuts, Screw Heads, etc.

*Item No. 7:*
$\frac{1}{2}'' \times 1\frac{1}{2}''$ Set Screw.
$E = A = \frac{1}{2}''$.
$C = 2\,A = 2 \times \frac{1}{2}'' = 1''$.
$B = \frac{7}{8}\,A = \frac{7}{8} \times \frac{1}{2}'' = \frac{7}{16}''$.
$D = \frac{3}{8}\,A = \frac{3}{8} \times \frac{1}{2}'' = \frac{3}{16}''$.

The computations for each item must be kept as shown, and as many items should be placed on a sheet as possible without crowding.

Having computed the dimensions of all the parts to appear on Drawing C–104, block out the space to the best advantage, and complete the drawing, keeping in mind the following facts:

Conventionally drawn threads begin and end with a *short* line. (See page 72, Fig. 49.)

Bolts are threaded any desired length, and the check nut is usually screwed on the bolt *first*, then the ordinary nut.

Cap screws up to and including 1″ diameter by 4″ long are threaded for three-quarters of their length and those above 1″ in diameter are threaded one-half their length.

**85. Tracing Drawing C-102.** After submitting drawing C–104 and making a blueprint of tracing C–101, trace the finally approved pencil drawing C–102. *Follow specific instructions previously given* in so far as they apply to this exercise.

**86. Tracing Drawing C-103.** After submitting tracing C–102, trace the approved pencil drawing C–103. *Follow specific instructions previously given* in so far as they apply to this exercise.

**87. Drawing C-105.** Make a mechanical drawing from sketches of the following parts:

Tail Stock Center, see Fig. 101, page 144, also sketch #3, page 145. — Shell,* see Fig. 103, page 144, also sketch #4, page 146. — Tail Stock Spindle,* see Fig. 102, page 144, also sketch #4, page 146. — Tail Stock Spindle Clamp,* see Fig. 113, page 150.

Before starting this drawing read, and prepare for examination on, paragraphs, as follows:

* Dimensions for these parts are to be obtained by making direct measurements of the objects themselves. See page 32, § 29, and page 94, § 62.

Conventional Methods, page 87, § 59. — Drawing to Scale, page 90, § 60. — Dimensioning Working Drawings, page 94, § 62. — Notes on a Drawing, page 97, § 63. — Indicating the Finish of Surfaces, page 98, § 64. — Use of Record Forms and Titles, page 98, § 65.

*Follow specific instructions previously given* in so far as they apply to this exercise. Give special attention to arranging the views and filling in the Bill of Material.

**88. Drawing C-106.** Make a full-size longitudinal section of the Tail Stock with all its parts assembled. See Frontispiece.

Before starting this drawing read, and prepare for examination on, paragraphs, as follows:

Sectioning and Sectional Views, page 79, § 55. — Assembly Drawings, page 86, § 58. — Dimensioning Working Drawings, page 94, § 62. — Time Keeping in Drawing, page 105, § 71.

*Specific Instructions.* To get all the necessary information for making this drawing refer to the approved Drawing C–105, also figures and sketches, as follows:

Tail Stock Main Casting, Fig. 117, page 152, also sketch #9, page 153. — Tail Stock Screw, Fig. 114, page 150, also sketch #8, page 151. — Tail Stock Hand Wheel, Fig. 107, page 147, also sketch #5, page 148. — Tail Stock Special Nut, Fig. 115, page 150, also sketch #8, page 151. — Ordinary Nut, Fig. 89, page 128.

The title of this drawing is *ASSEMBLED TAIL STOCK.*

Go over the drawing carefully before submitting same, to see that all lines, dimensions, etc., are up to the required standard.

**89. Tracing Drawing C-106.** *Follow specific instructions previously given* in so far as they apply to this exercise.

**90. Examination on Chapter III.** As a final examination any drawings assigned are to be made of Lathe Parts or of any other machine, and examination questions concerning previous work (including Drawing C–105) will be asked. As a general review, in preparation for examination, carefully read paragraphs on pages 71 to 116 inclusive; also § 12, page 13, and § 28, page 31.

## CHAPTER IV

## FREE-HAND WORKING SKETCHES

**91. Introductory.** The ability to make a good free-hand working sketch is an accomplishment of great value to the engineer. Much less time is required to make a free-hand sketch than a mechanical drawing, and in developing a design it frequently occurs that there are several solutions to the problem, and that the best may be as easily determined from a sketch as from a more elaborate mechanical drawing. If definite movements must be provided for, the vital positions of the related parts may be shown in skeleton outlines drawn to scale with instruments and each important element or part needed to be drawn can be sketched in free-hand.

In commercial drafting rooms preliminary sketches of new ideas are often filed away to be worked up later into detail mechanical drawings. Such sketches serve as a visible record of the idea and may prove valuable in establishing a priority claim for a patent.

Another common use of technical sketches is found in detailing parts that must be renewed and for which no drawings exist. Also in making additions or alterations, drawings of a machine may not be available and yet, in order that the new parts fit into position and act without interference, a drawing may be necessary. Whenever data must be obtained from machines in existence, a record of all measurements is usually made on a free-hand sketch, and the ability to make a clear sketch, accurately dimensioned, complete in all respects, and free from mistakes and oversights so that additional trips to the machine for further information are not necessary, is of great value to the draftsman or engineer.

**92. Free-hand Copies of Working Drawings.** To beginners the value of making free-hand sketches from mechanical drawings is to *train the hand* to make good free-hand lines, and the

*eye to judge proportion*, so that the ability to scheme work and to plan details without using the drawing instruments will be acquired.

93. **Free-hand Sketches from Objects.** It must be understood that working sketches as discussed here are not *perspective* representations of the object, but economical substitutes (both as to time and cost saved) for mechanical drawings. If the sketch is proportioned accurately (say on cross-section paper) in accordance with measurements of the object, it is in reality a working drawing, differing from a mechanical drawing only in that it is made *free-hand.*

In making sketches from the object the beginner often considers the dimension figures the only important feature of the work, and makes the drawing so crude that other persons cannot work from it. Such a sketch is of very little value. If a sketch is to be a permanent record it must be so clear and complete that *any one* will be able to work from it, and this cannot be done unless the actual drawing is well executed. On the other hand if the sketches accurately *represent* the object it may not be necessary to have *all* the dimensions recorded exactly as they measure on the object. For example, **rough castings and forgings** will vary in thickness, and a part intended to be symmetrical about a center line will often deviate without apparent reason. *The beginner must learn to make a distinction between dimensions* as some measurements must be recorded more exactly than others. For example, if a pipe flange measured $15\frac{1}{4}''$ in diameter, a $15''$ flange could be recorded, but if the standard bolt circle of a pipe flange should be $13\frac{1}{4}$,″ it must be so recorded, or the flange will not match others drilled according to the standard. The degree of refinement exercised in **recording measurements between unfinished ends of a casting** or between one finished and one rough end will depend on the size of the casting. **In very small castings,** such as the small parts of the lathe, dimensions can be frequently "rounded off" to, say, the nearest $\frac{1}{8}''$, but measurements made between surfaces of **parts which fit to other parts** of a machine must be made with *extreme* accuracy. Center lines

and lines of symmetry must also be carefully located, and wherever possible measurements should be made from such lines or from finished surfaces.

**A sketch made without direct measurements of the object** has no definite scale but is proportioned *by the eye*. In such cases the proper relation of distances, i.e., lengths of lines, is secured by making comparisons. The relative *width* of a part is compared to its *length*, and if a detail on the machine is one-fourth as long as the over-all dimension, it should be drawn one-fourth as long as the over-all on the drawing. To assist in **making an eye estimate of a distance,** hold the pencil between the eye and the object and so that the thumb nail can be moved along its length (see Fig. 90); sight along one end of the pencil

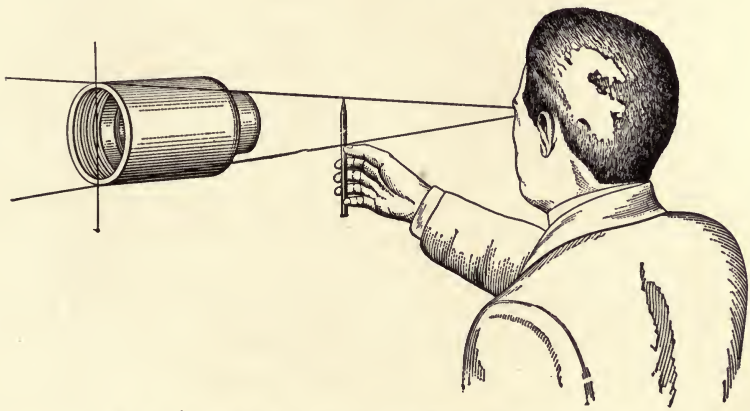


**Fig. 90. — Estimating Proportion by Means of the Eye and a Pencil.**

and bring it *in line* with the end of the part being measured; move the thumb along the pencil until it sights the opposite end. This length along the pencil is then compared with the length of the over-all dimension *similarly measured*. In the figure the two diverging lines represent the limits of the *angle of sight*. The left eye usually is closed when estimating. The special precautions necessary in this method are that the pencil shall always be held the *same way and the same distance* from the eye, and the lengths, being compared on the object, shall be approximately the *same distance* from the eye. The pencil should be held at arm's length in making measurements, as this insures the

distance being kept constant. In this method of estimating proportionate lengths no one estimated length should be greater than a convenient length on the pencil, but the distance from the eye to the object being sketched should be such that the estimating can be on the largest scale possible. The sketch can be made to any desired scale, *provided the proportions of the sketch* are kept the same as estimated with the pencil. This method of making a sketch of an object is *equivalent* to tracing each line of the object on a pane of glass which is held at arm's length and in a plane at right angles to an *imaginary line* drawn from the eye to the "center" of the object.

**94. Making Sketches from Memory.** The beginner should occasionally make sketches from memory. For this purpose select some *simple* object, or mechanical drawing, and after making a careful study of the object or drawing, make free-hand sketches comprising all necessary views and accurately dimension them *from memory.*

**95. The Free-hand Pencil Line.** The first essential in making free-hand sketches is to learn to draw a *finished free-hand* line. This requires, first, that the *direction* of the line and, second, that the *quality* of the line be correct. That is, the lines must have the proper direction and relation to one another to correctly represent the outline of the object, and they must also be *perfectly* smooth and clear-cut, see page 78, § 54, so as to present a satisfactory appearance.

**A good method of drawing a free-hand straight line is as follows:**

(1) *Sketch in very lightly a series of short dashes to follow as closely as possible the exact direction required of the line.* See Fig. 91(a).

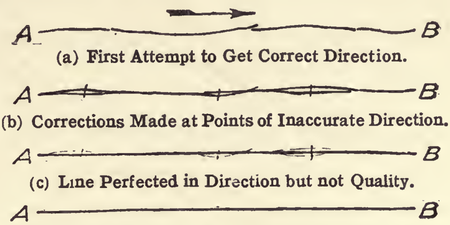
(2) *Correct the main portions which are out of true, locating these by sighting along the line and marking inaccuracies.* See Fig. 91(b).

(3) *Retrace the line, which is now true in direction but "sketchy" in quality, making it uniform and of medium weight.* See Fig. 91(c).

(4) *Erase all preliminary work, and, as the true line is made*

*dim in the process, retrace it with the longest strokes possible, leaving it true in direction and finished in quality.* See Fig. 91(d).

Use a **HHHH** pencil with conical point (see page 15, § 14), and as the first attempt will seldom result in a line true in either direction or quality, all *preliminary* work must be done with very light lines. The pencil should be moved toward the right [see Fig. 92(a)] when drawing lines which are horizontal or nearly so, and toward the body or



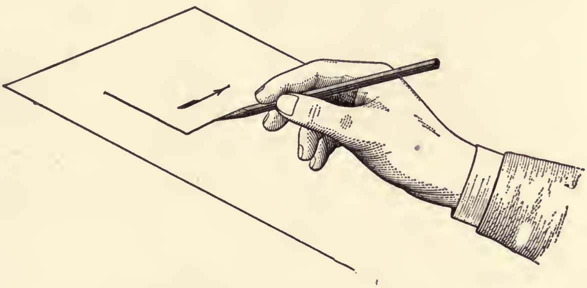

**(a) First Attempt to Get Correct Direction.**

**(b) Corrections Made at Points of Inaccurate Direction.**

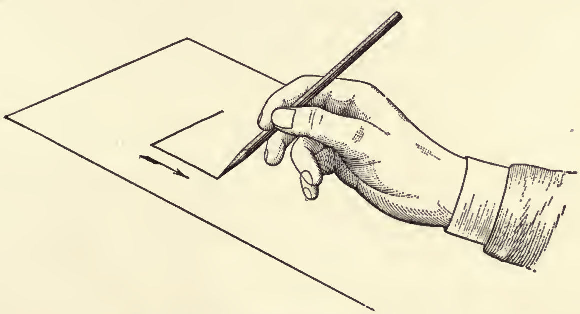
**(c) Line Perfected in Direction but not Quality.**

**(d) Line Perfected in Both Direction and Quality.**

**Fig. 91. — Drawing a Free-hand Line.**



**(a) Drawing a Horizontal Free-hand Line.**



**(b) Drawing a Vertical Free-hand Line.**

**Fig. 92. — Method of Holding the Pencil to Draw a Free-hand Line.**

downward [see Fig. 92(b)] when drawing lines which are vertical or nearly so. In drawing free-hand lines it is very important

that the pencil be held "freely" and not with a *strained* grip and the relation of the pencil, the fingers and the paper is shown in Fig. 92. Motion to the pencil or pen should not be given by movement of the fingers but by an easy movement of the hand and forearm. When a finished line, straight or curved, is drawn with more than one stroke of the pencil, considerable care must be exercised in joining the segments, so that the line will be continuous and appear to have been drawn at a single stroke. **A curved line** is drawn by locating a series of points to mark its direction, and then proceeding as with the straight line. *Do not erase the first lines drawn* but only that portion which does not follow the direction desired. This leaves portions of the line to act as a guide and the final line is brought to its proper direction and traced in somewhat heavier than the preliminary lines. When a line has been drawn exact in direction, *all* preliminary work, and as much of the true line as is necessary to destroy the appearance of the *short sketchy strokes*, is erased (using a clean eraser and when necessary an eraser shield), and the line is finally *retraced* and made of satisfactory quality.

**96. Free-hand Inked Lines.** The beginner should not ink any work unless the original pencil work has been checked and approved.

**To draw an inked free-hand line,** fill the pen with an average amount of ink, and, holding the point at the *beginning* of the line, slightly press the pen until the ink begins to flow (which is indicated by a dot of ink on the drawing), then with an *even* pressure continue from that point, making the line uniform in width from start to finish.

**The width of the free-hand inked line will depend on the following conditions:**

(1) *Fineness of the pen point.*

(2) *Pressure exerted on the pen.*

(3) *Condition of the pen point as regards cleaniness, i. e., whether there is dried or partially dried ink on the point.*

(4) *Amount of ink carried on the pen.*

(5) *Speed at which the pen is moved when drawing the line.*

In general, *free-hand* inked lines should be formed with strokes *toward* the draftsman, or in a *right-hand* direction. (See Fig. 92, page 135.) Upward strokes of the pen should be avoided as much as possible, as the pen point is liable to catch in the drawing and splash the ink; also this is not the most natural way to make free-hand lines.

Care must be exercised in **joining two segments** of a line when inking, otherwise the point at which they are joined is easily detected and the completed line will not present a *finished* appearance.

To get **the best results** there should be a steady and uniform flow of ink from the pen, and this is best secured by frequently cleaning and refilling the pen.

**Too much ink** on the pen will make a blot or a line of greater width than desired, while **too little ink** dries upon the points and obstructs the free flow of the ink from above. Frequent filling of the pen tends to maintain an *average* quantity of ink and overcomes both of these difficulties. If too much ink has been gathered on the pen point touch the pen to the neck of the bottle to permit the surplus ink to flow back into the bottle.

Always clean the pen point thoroughly before putting it away.

**97. Building up a Sketch.** To start a sketch, study the part to be represented and determine the view which shows the *most essential features* and from which related views can be best obtained. *The relation of views and the principles underlying machine sketching are exactly the same as for mechanical drawings.* (See page 73, § 53.)

Having determined the views (and sections, if any are necessary) and the size of the views, draw in the main center lines in such a position that when the views are completed they will be arranged symmetrically on the sheet and present a neat appearance.

**In beginning each view,** draw several of the most important limiting lines first, and then fill in the detail parts.

In general it is best to work *from the center* of a view, i.e., from the center lines, or from the central parts outward.

Always complete the views satisfactorily before putting in reference lines, dimension lines, and arrowheads.

The outline of one view should be completed *as far as possible* before starting another. In working up views it is often convenient to **use a strip of paper to transfer the principal dimensions** from one view to another. When **a circle or circular arc** is to be drawn, several points should be marked off equally distant from the center and the curve drawn through them.

In some cases it may be found best to draw in the *principal* dimensions of the object to scale and finish up the detail parts of a view free-hand; but sketching as a rule is not done to scale, although the proportions are made approximately correct.

Draw in all the dimension lines and arrowheads, but *do not put in dimension figures until the last.*

**Draw all lines very lightly at first,** and, after inaccuracies have been corrected, retrace the sketch and make the lines of medium weight.

When the correct outlines of all views have been drawn of *medium weight,* the entire sheet is to be cleaned with the sponge rubber or art gum (see page 16, § 15), and such other erasing done with the pencil eraser as is necessary. Then all the dimmed lines of the views should be retraced and made of the desired weight.

**98. Title-form on Small Sheets.** Where the drawing sheet is *small* a small title-form is preferable, and this title-form is usually located in the lower right-hand corner.

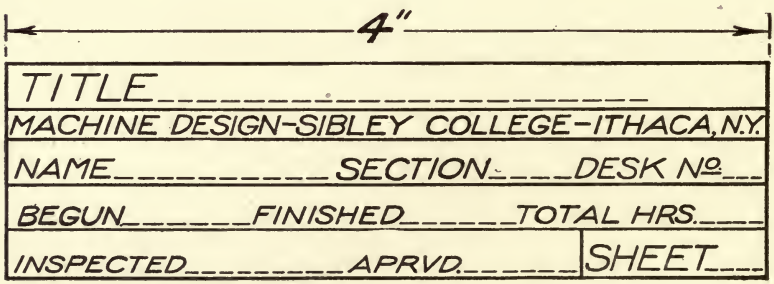



**Fig. 93. — Title-form to be used in this work on small sheets.**

There is no accepted standard title-form, but the one shown in Fig. 93 represents a general average and will be used in this work on all drawing *sheets* of the $8'' \times 10\frac{1}{2}''$ size.

All lettering in title-form, unless otherwise specified, is to be of the slant Gothic style and is to be carefully arranged and properly proportioned.

99. **Size and Numbering of Sketch Sheets.** Exercises in sketching will be done on small sheets of standard letter size ($8'' \times 10\frac{1}{2}''$), heavy weight, cross-section paper ruled on one side (see page 5, § 4) and punched for standard #10 Manila cover.

The order in which free-hand sketch sheets are executed will be indicated by *Arabic* numbers beginning with No. 1 and continuing as far as necessary, and the title-form is to be as shown in Fig. 93, page 138.

## SET OF FREE-HAND DRAWING EXERCISES

100. **Sheet #1.** The sketches on this sheet consist of a Shim (see Fig. 94) for the bearings, a Small Stud (see Fig. 95) and a Clamp Stud (see Fig. 96) for the tail stock of the Lathe. Fig. 97, page 140, shows the general layout of this sheet.

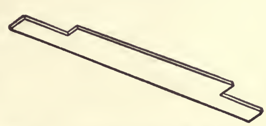


**Fig. 94. — Perspective of Shim.**

The exercises on this sheet give practice in making sketches of objects requiring only one view, and in drawing free-hand lines and arrow-heads. Note especially how the diameters of bolts are shown. This method applies to such parts as bolts, screws, etc., but **the diameters of circular parts** in general should be given on the view showing the circle.

**Fig. 95. — Perspective of Stud.**

*Before beginning this sheet* determine, either from referring to the actual machine or else to the frontispiece, exactly where each piece is located, and its purpose on the finished machine, also what other parts it must fit into or against.

**Fig. 96. — Perspective of Clamp Stud.**

For full information as to the general system to be followed see page 175, Appendix A.

Study, and prepare for examination on, paragraphs, as follows:

Thumb Tacks, page 8, § 9. — Pencil Pointer, page 14, § 13.

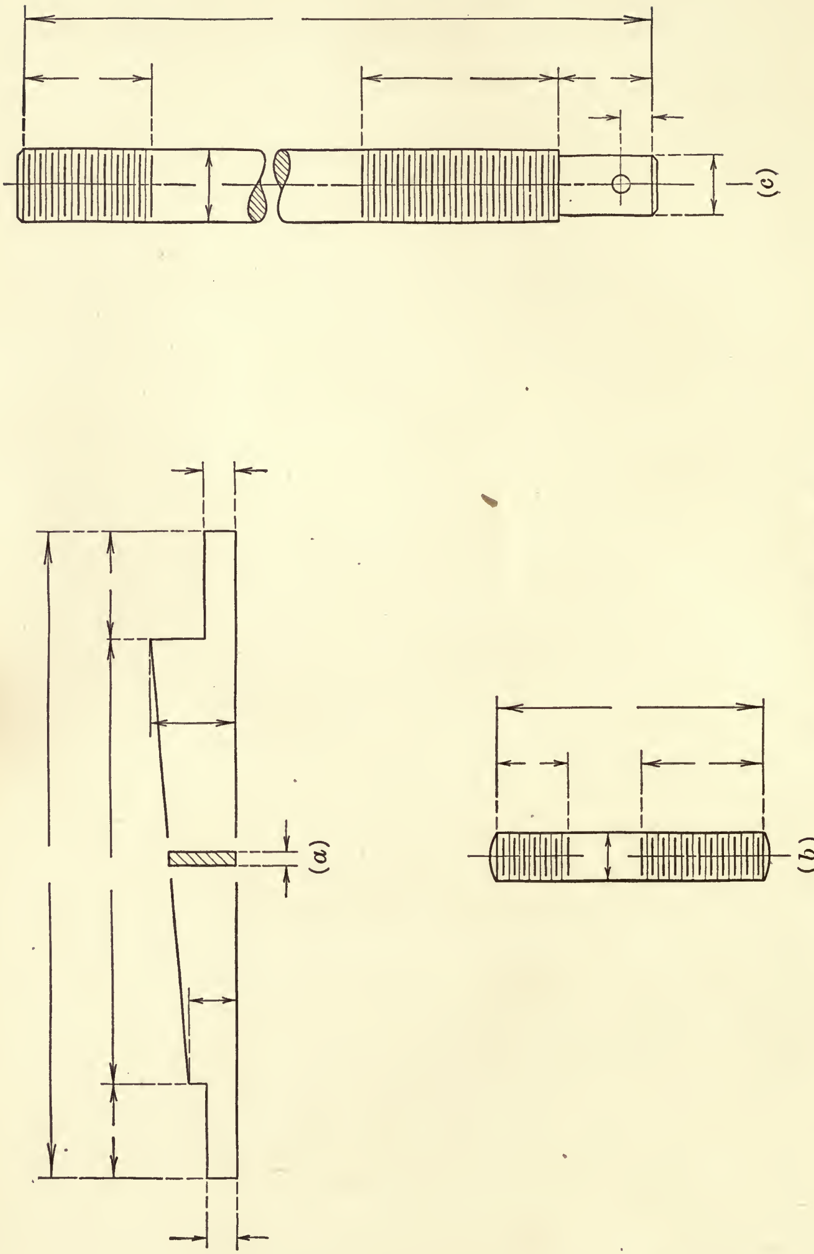



Fig. 97.—Model for Sheet No. 1.

— Lead Pencils, page 14, § 14. — Erasers and Erasures, page 16, § 15. — Conventional Lines, page 76, § 54. — Checking Drawings, page 113, § 76. — Introductory, page 131, § 91. — The Free-hand Pencil Line, page 134, § 95. — Title-form for Sheets, page 138, § 98. — Size and Numbering of Sketch Sheet, page 139, § 99.

*Specific Instructions.* (*a*) Fasten the sheet on the small drawing board. (See page 2, § 2.) (*b*) Stamp in and fill out Title-form. (See page 138, § 98.) The title of this sketch is *LATHE DETAILS.* (*c*) Copy the sketches, being careful to see that the work is correct in every particular.

Use a HHHH pencil and draw the sketches free-hand on cross-section paper. Group the figures centrally on the sheet in about the relative position and proportion shown in Fig. 97, page 140.

In making the sketch of the Stud, the *center line is drawn first* and the sketch built symmetrically about it. All center lines, reference lines, dimension lines, and arrowheads are to be drawn in.

Do not make any measurements with scale or dividers, but proportion the sketches by eye. (See page 133, § 93.) (*d*) Thoroughly examine the work to see that nothing has been omitted; correct any errors, and after inspection write, with ink, the Date Finished and Total Actual Hours, and submit the sheet for checking and approval.

**101. Sheet #2.** The sketch on this sheet (see Fig. 99, page 143) consists of three views of the main casting of the Headstock (see Fig. 98, page 142) of the Lathe. All dimension figures on Fig. 99 represent the number of *spaces* between arrowheads and *not the number of inches.*

The purpose of this exercise is to illustrate the use of cross-section paper; to provide practice in making free-hand curved lines, and in making a sketch of an object which requires *several* views.

The relation of the different views of this sketch to one another *must be carefully studied,* and the sketch *not merely copied.*

Before starting this work read, and be prepared for examination on, paragraphs, as follows:

Cross-section Paper, page 5, § 4. — Erasing Shield, page 17, § 16. — Projection and Projected Views, page 73, § 53. — Num-

ber and Arrangement of Views, page 83, § 56. — Dimensioning Working Drawings, page 94, § 62. — Indicating the Finish of Surfaces, page 98, § 64. — Free-hand Copies of Working Drawings, page 131, § 92.

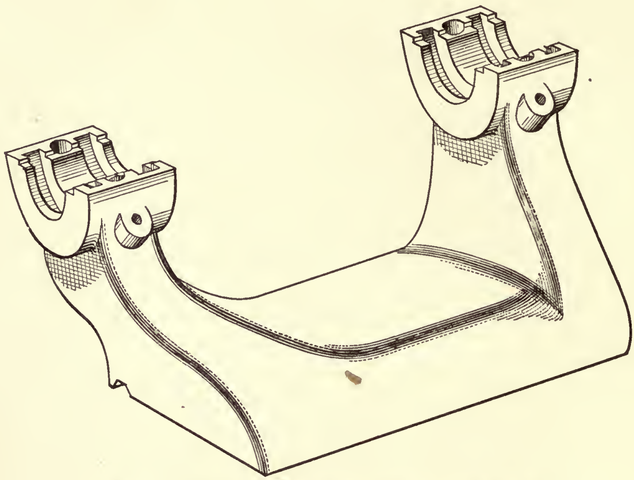


**Fig. 98. — Perspective of Main Casting of Headstock.**

Determine the location and purpose of the Headstock. See Frontispiece.

*Specific Instructions.* (*a*) Fasten the sheet on the small drawing board. (See page 2, § 2.) (*b*) Stamp in and fill out title-form. (See page 138, § 98.) The title of this sketch is *LATHE DETAILS.* (*c*) Having located main center lines, refer to the "space dimensions" given in Fig. 99 and accurately locate a sufficient number of points to determine the outline of the *side view* (*a*), which is then sketched in *very lightly.* The end views are next drawn.

After all views have been completed in a satisfactory manner, clean the sheet and retrace all lines, making them clear-cut and of the desired weight.

Having gone over the work and brought it to the highest standard possible, submit the sheet for approval.

**102. Sheet #3.** The sketches on this sheet represent a Face Plate (see Fig. 100, page 144), a Tail Stock Center (see Fig. 101,

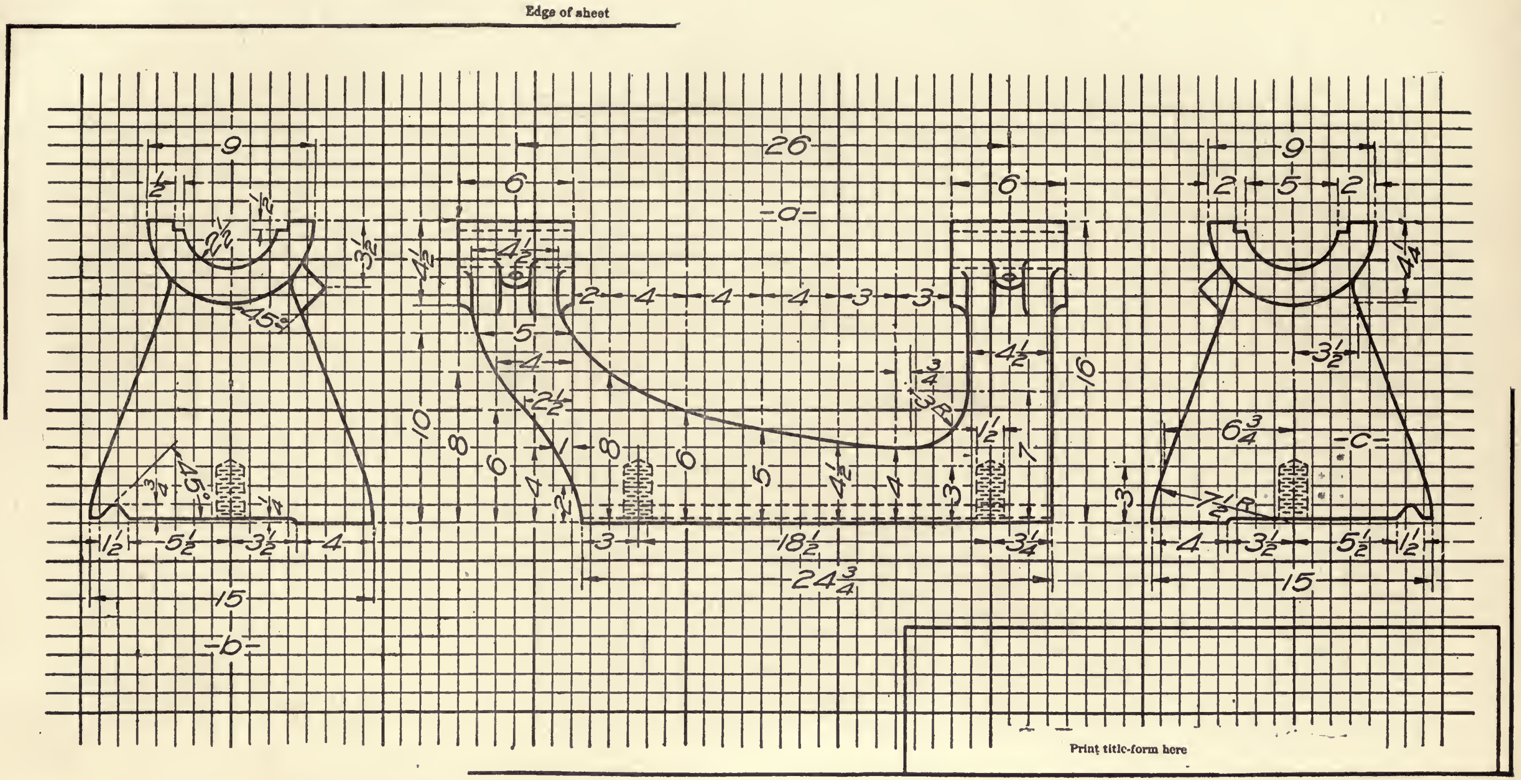



Fig. 99.—Layout for Sheet No. 2.

p. 143

page 144), and a Special Nut (see Fig. 80, page 117) for headstock spindle. Fig. 104 shows the general layout of this sheet.

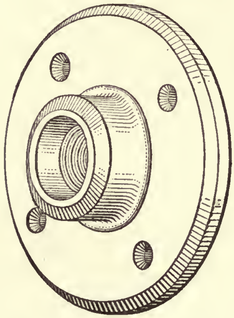


Fig. 100. — Perspective of Face Plate.

The purpose of the exercises on this sheet is to provide practice in free-hand sketching and in making a working drawing which will have all dimensions, notes, and other data necessary for the construction of the parts in the shop. Before starting this sheet study the system of dimensioning, noting especially how circles, arcs, angles, and tapers are dimensioned, and how related dimensions are kept together.

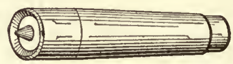


Fig. 101. — Perspective of Tailstock Center.

Study and prepare for examination on paragraphs as follows:

Detail Drawings, page 85, § 57. — Conventional Methods, page 87, § 59. — Indicating the Finish of Surfaces, page 98, § 64. — Use of Record Forms and Titles, page 98, § 65. — Making Sketches from Memory, page 134, § 94.

What is meant by "counterbore" and "countersink." How do you determine the number of threads per inch on a given diameter?

*Follow the specific instructions previously given* in so far as they apply to this sheet.

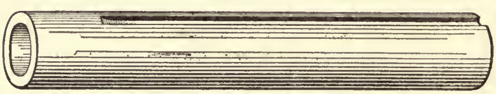


Fig. 102. — Perspective of Tailstock Spindle.

**103. Sheet #4.** The exercises on this sheet are sketches of the Tail Stock Spindle (see Fig. 102) and Shell (see Fig. 103).

These exercises illustrate the method of representing simple symmetrical parts in the clearest way possible with the minimum amount of drawing. Fig. 105 gives the general layout of this sheet.

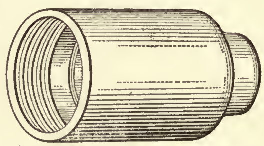


Fig. 103. — Perspective of Shell.

Before starting this work read, and be prepared for examination on, paragraphs, as follows:

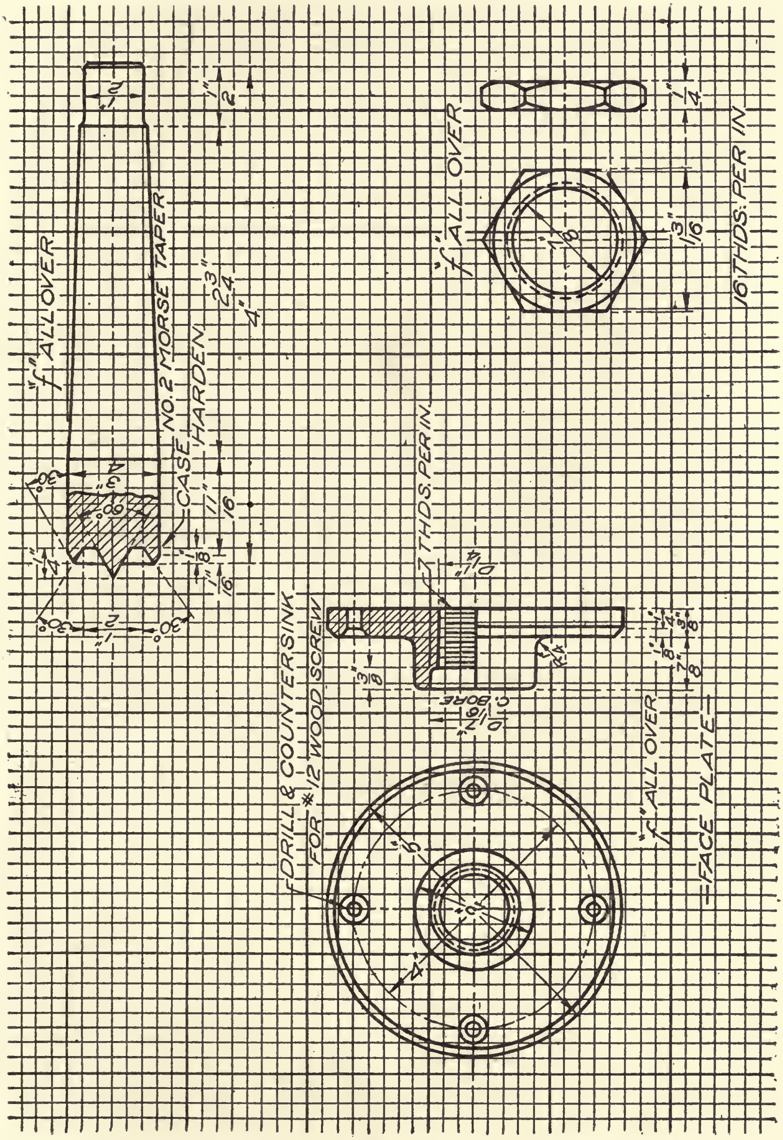



Fig. 104.—Layout for Sheet No. 3.

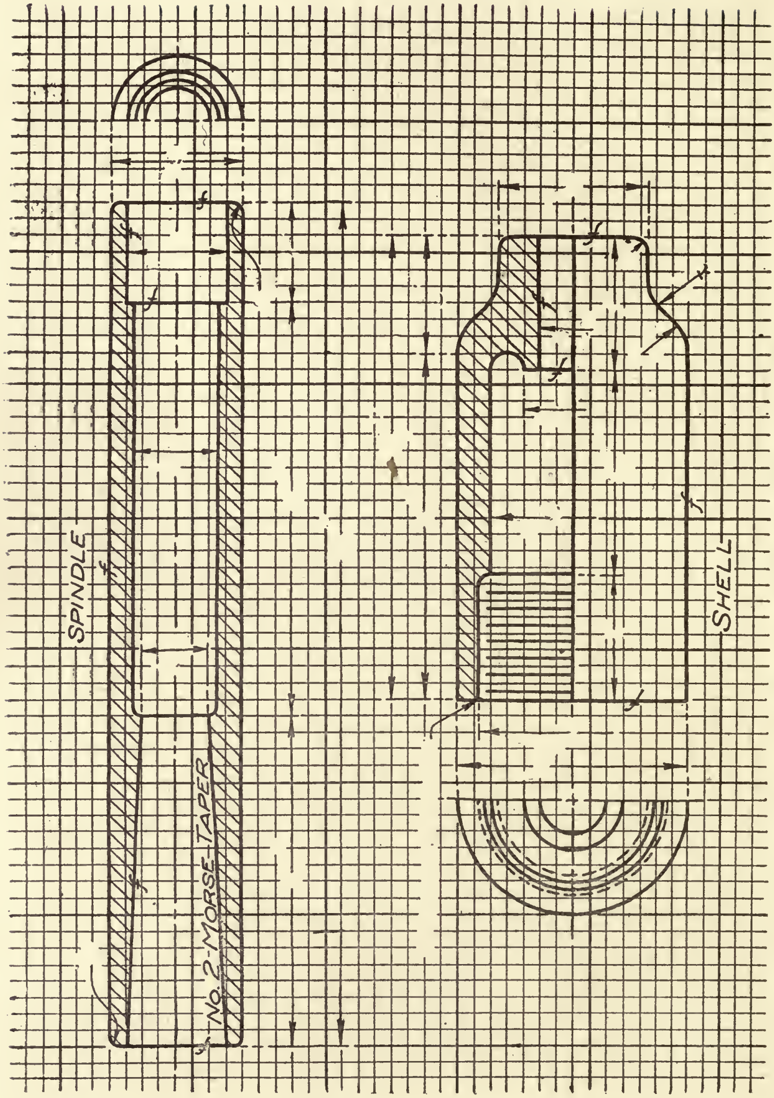



Fig. 105.—Layout for Sheet No. 4.

Sectioning and Sectional Views, page 79, § 55. — Notes on a Drawing, page 97, § 63. — The Title form on a Drawing, page 100, § 66.

**104. Sheet #5.** The exercises on this sheet consist of sketches of the Clamp Bolt (see Fig. 106) the Hand Wheel (see Fig. 107) and the End Cap (see Fig. 108). Fig. 109, page 148, gives the general layout of sheet.

Fig. 106. — Perspective of Clamp Bolt.

The system of dimensioning is *the main point* to be noted in sketching these parts. Dimensions which are related are kept together, as, for example, the partial dimensions making up the length of the Clamp Bolt. These are given on the same side of the view and not scattered. With partial dimensions, an overall dimension is given, which of course must be the sum of the partial dimensions.

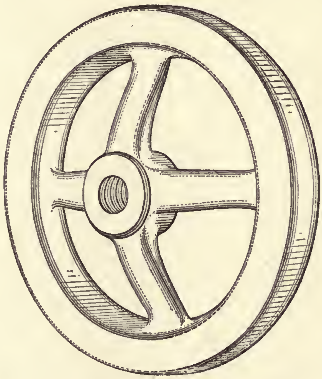


Fig. 107. — Perspective of Hand Wheel.

Note also the method of dimensioning curves; the different views in which the different diameters are shown on the drawing; the method of "turning up" the section in the arm of the hand wheel, and that in the section of the hand wheel the arms are *not* sectioned, although the cutting plane passes through them.

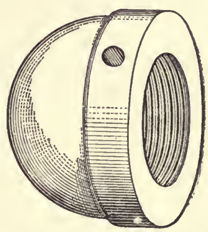


Fig. 108. — Perspective of End Cap.

**105. Sheet #6.** The exercises on this sheet consist of three undimensioned views of the Clamp (see Fig. 111, page 150). Fig. 110, page 149, gives the general layout of this sheet which is to be copied and then the dimensions filled in from measurements taken on the Clamp that the drawing illustrates.

Before drawing this sheet read, and be prepared for examination on, paragraphs, as follows:

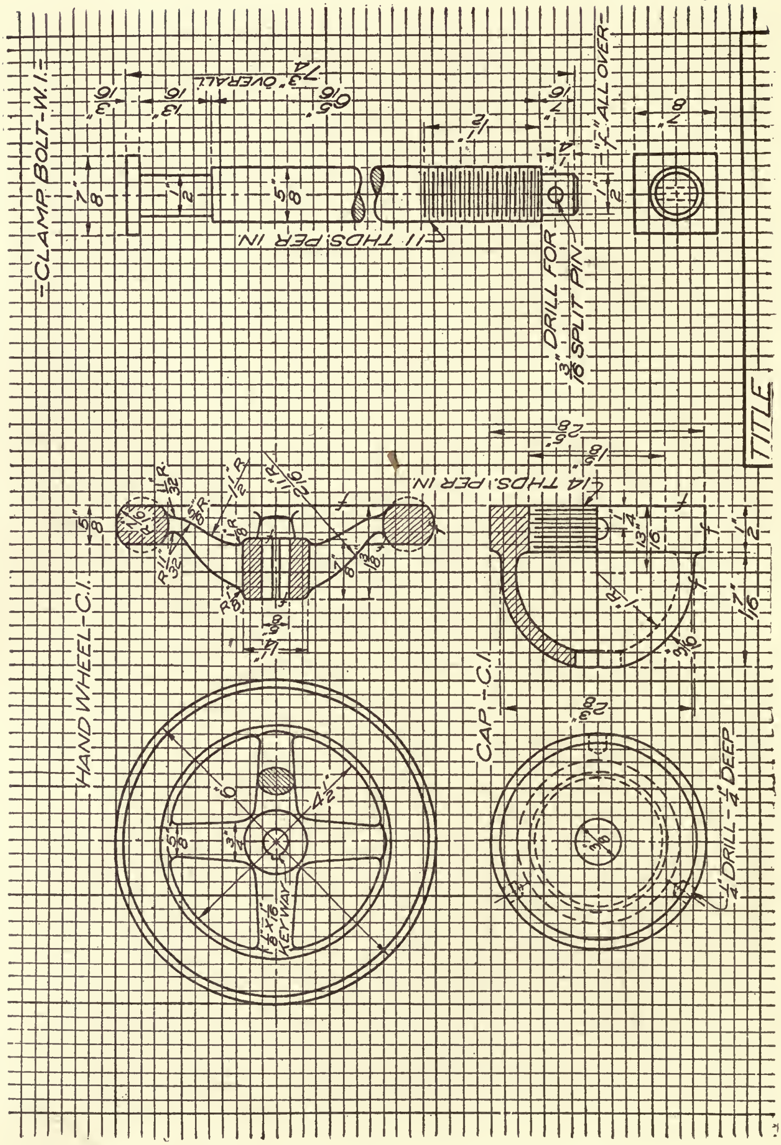



Fig. 109.—Layout for Sheet No. 5.

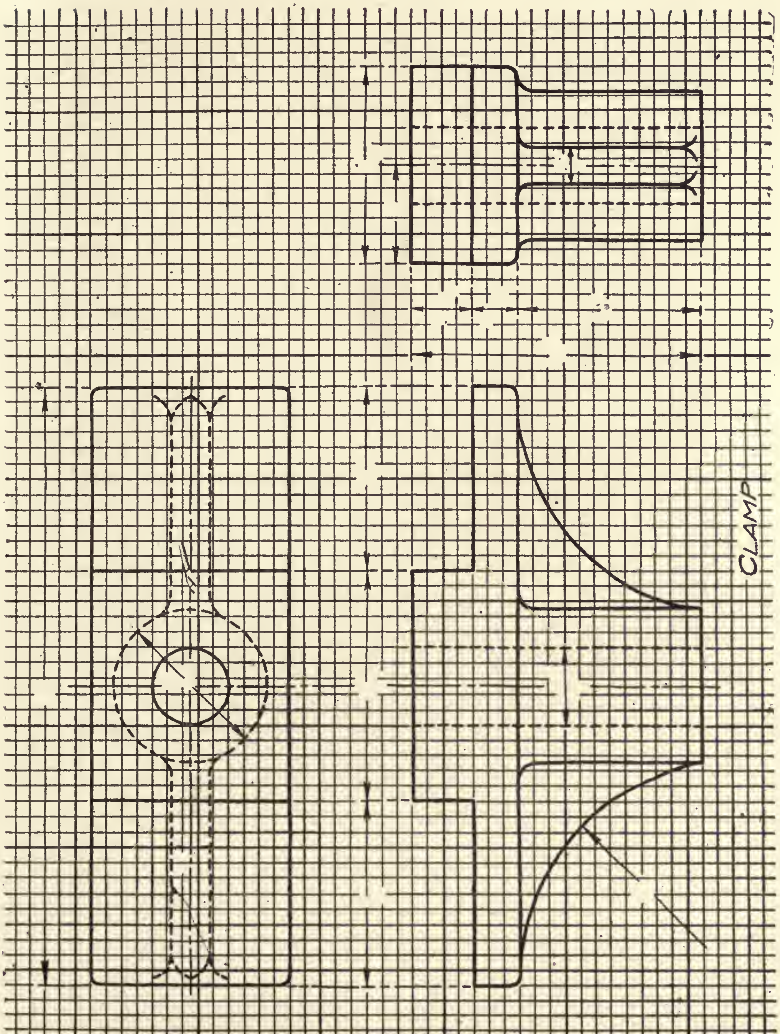



Fig. 110.—Layout for Sheet No. 6.

Machinist's Calipers, Dividers and Steel Rule, page 32, § 29. — Choice of Scale in Drawing, page 93, § 61. — Dimensioning Working Drawings, page 94, § 62. — Notes on a Drawing, page 97, § 63. — To make a Pencil Drawing, page 108, § 74. — Free-hand Sketches from Objects, page 132, § 93.

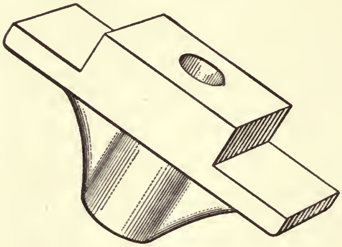


Fig. 111. — Perspective of Tailstock Clamp Strip.

**106. Sheet #7.** Make sketches of the Tool Rest Support Slide (see Fig. 112) and of Clamp for Tailstock Spindle (see Fig. 113). This sheet is to be *made directly from these parts.*

Before starting the work read, and be prepared for examination on, paragraphs, as follows:

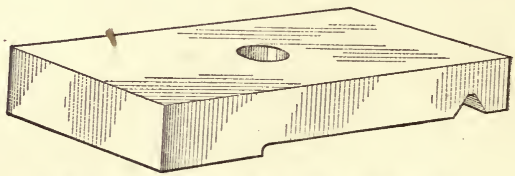


Fig. 112. — Perspective of Tool Rest Support Slide.

Projection and Projected Views, page 73, § 53. — Drawing to Scale, page 90, § 60. — Notes on a Drawing, page 97, § 63. — Building up a Sketch, page 137, § 97.

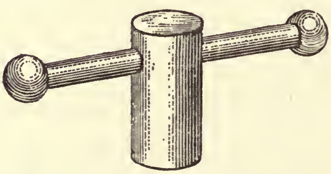


Fig. 113. — Perspective of Tailstock Spindle Clamp.

Determine the purpose and location of the above parts on the lathe.

**107. Sheet #8.** Make sketches of the Tailstock Screw (see Fig. 114) and the Nut (see Fig. 115) following the general layout shown in Fig. 116, page 151. Determine the location and purpose of each of these parts on the lathe and be prepared for

Fig. 114. — Perspective of Tailstock Screw.

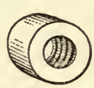


Fig. 115. — Perspective of Tailstock Nut.

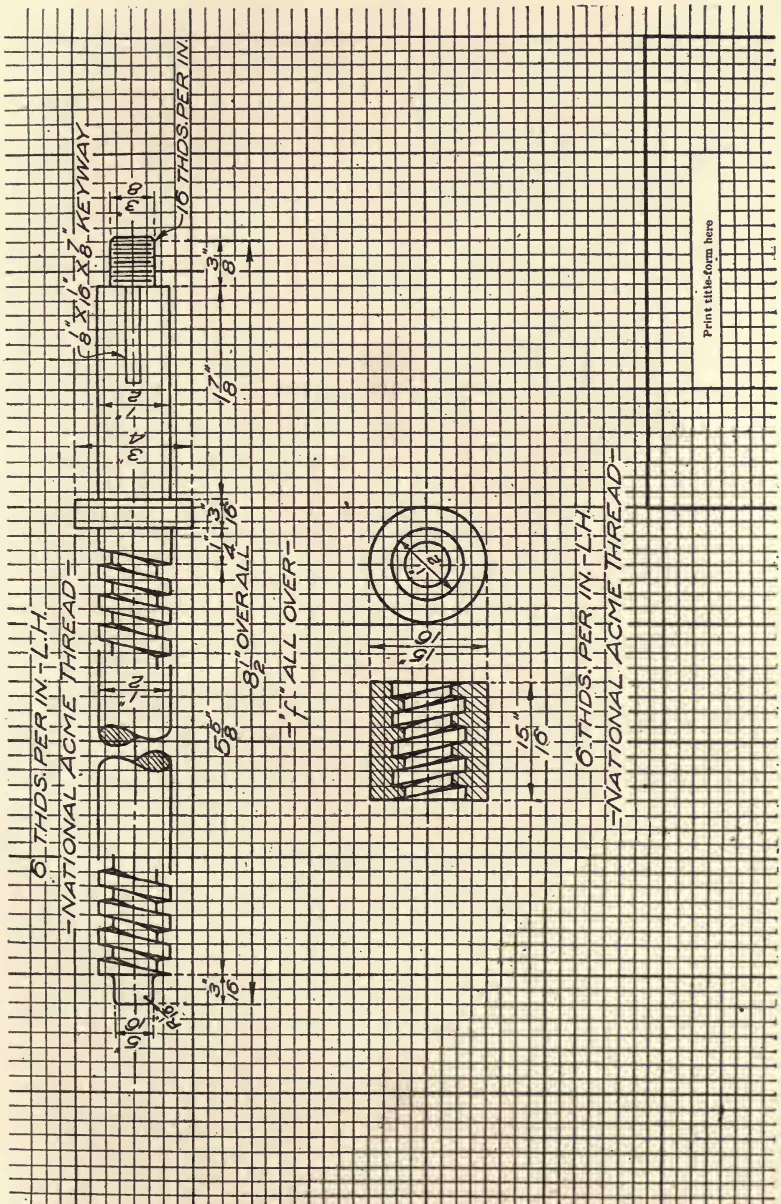



Fig. 116.—Layout for Sheet No. 8.

examination on paragraph 59, page 87, with reference to Conventional Methods.

Copy sketch and fill in dimension figures *from measurements made on the objects* which are illustrated.

This sheet illustrates the method of showing and dimensioning keyways and the Acme National Thread (see page 88, section D, drawing c). Notice that the direction of the thread shown on the section of the nut is *reversed* from that on the screw and be able to explain the reason for this.

**108. Sheet #9.** Make a working sketch, showing three views of the main casting of the Tailstock (see Fig. 117).

Keep that portion of the surface of the drawing not in use covered with a clean piece of paper and avoid smearing the drawing. Fig. 119, page 153, shows the general layout for this sheet.

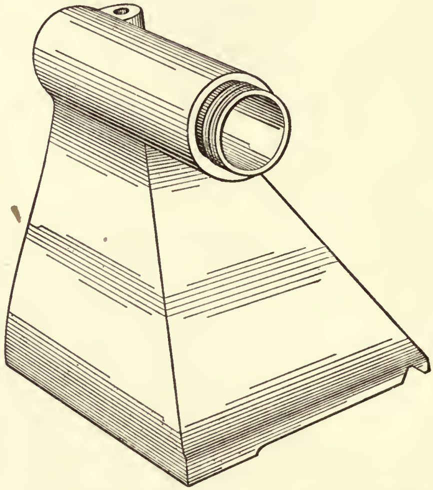


Fig. 117.—Perspective of Main Casting of Tailstock.

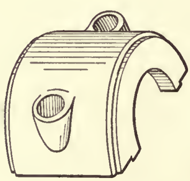


Fig. 118.—Perspective of Bearing Cap.

**109. Sheet #10.** Make working sketches directly from the Bearing Cap (see Fig. 118) and The Stationary Flange (see Fig. 120, page 154).

**110. Sheet #11.** Make working sketches of the Cone Pulley (see Fig. 121, page 154), on ordinary standard size paper (*not cross-section paper*) and see that the views are well proportioned. In practice sketches are frequently made on unruled paper.

**111. Sheet #12.** Make a copy of the sketch of the pattern and core box for the Cone Pulley (see Fig. 122, page 155).

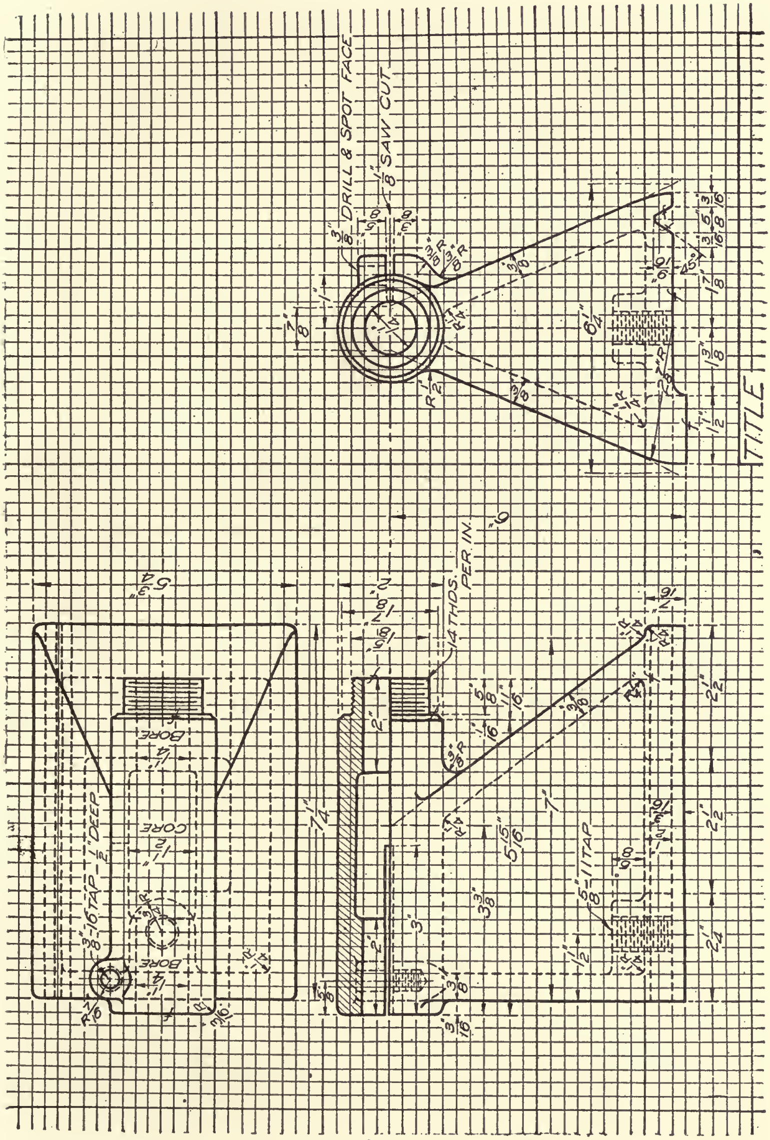



Fig. 119.—Layout for Sheet No. 9.

**112. Inking Sheet #1.** The purpose of inking this sheet is to give practice in making straight free-hand inked lines.

Where only a limited number of pieces are to be made from a drawing, it frequently happens that the work does not warrant the expense of making a tracing and a penciled sketch is not sufficiently permanent, therefore an *inked* sketch is made.

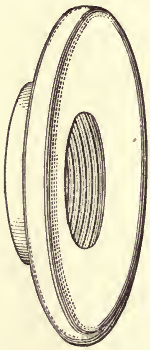


Fig. 120. — Perspective of Small Flange.

Before starting this exercise study, and be prepared for examination on, paragraphs, as follows:

Drawing Ink, page 18, § 18. — Ordinary Pens, page 18, § 19. — Penholders, page 20, § 20. — Conventional Lines, page 76, § 54. — The Free-hand Inked Line, page 136, § 96.

To avoid spoiling a pencil drawing practice making an inked line on a piece of scrap paper before starting to ink the penciled work. *Do not start inking until the penciled sketch has been checked and approved.*

**113. Inking Sheet #3.** The purpose of inking this sheet is to give practice in making inked curved lines free-hand.

**114. Inking Sheet #11.** This exercise gives practice in inking on ordinary paper.

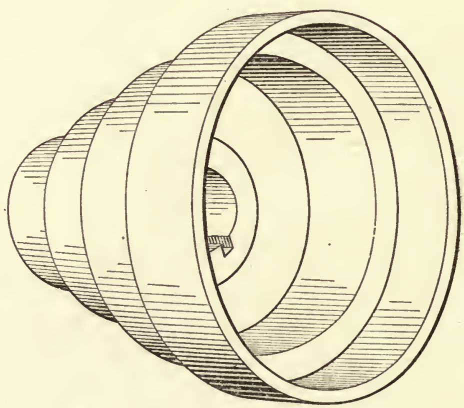


Fig. 121. — Perspective of Cone Pulley.

**115. Examination on Chapter IV.** As a final examination, any sketches assigned are to be made in pencil or in ink of Lathe Parts or parts of any other machine, this work to be done on plotting or on plain paper as directed. Also examination questions concerning the main subject matter of this chapter will be asked.

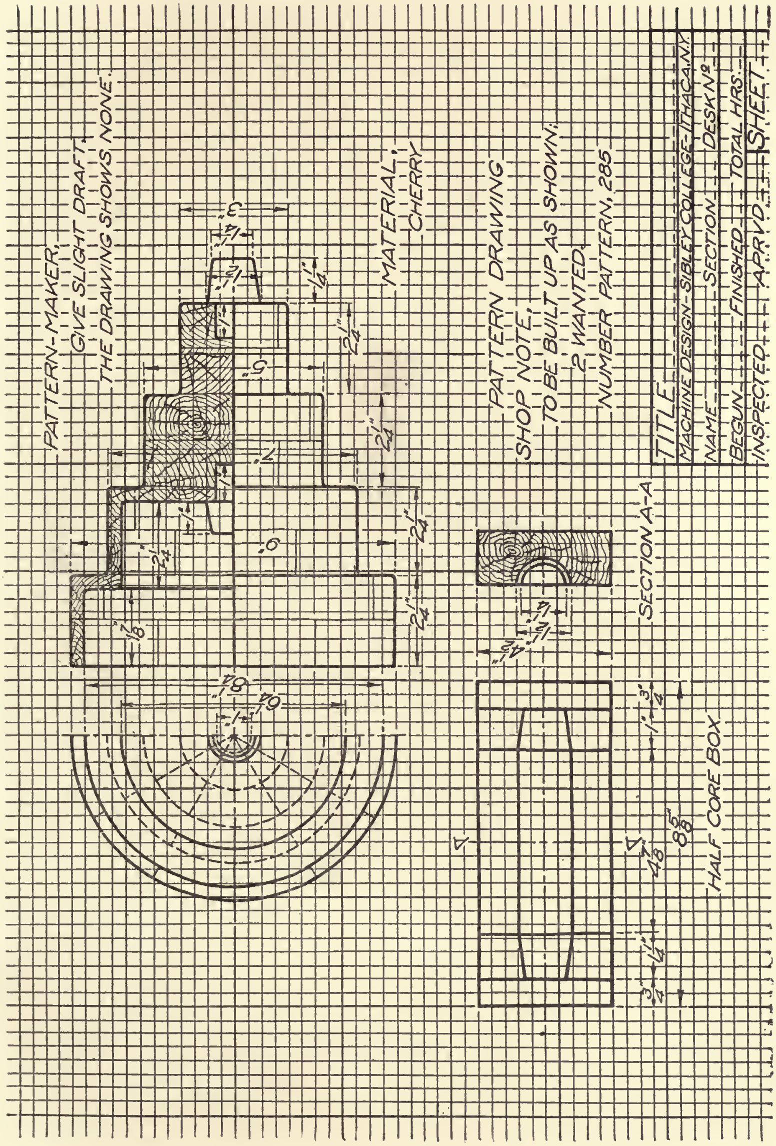



Fig. 122.—Layout for Sheet No. 12.

## CHAPTER V

## ISOMETRIC DRAWING AND SKETCHING

**116. Introductory.** Isometric drawings are often preferable to mechanical drawings because they are very easily understood, even by those who have little or no knowledge of *technical* drawing.

While mechanical drawings can be made so that they completely represent an object both as to its form and dimensions, *several views* are usually required to represent the object fully; and in order to read and understand such drawings it is necessary to *visualize* the object *from these views*. This usually requires considerable study on the part of the reader, and the disadvantages of mechanical drawings can be largely overcome by the use of **isometric drawings** to represent the object. Isometrics are coming to be used much more frequently in illustrating piping plans and layouts, structural details, " bird's eye " views of buildings, etc., although they have already been extensively used in making patent office drawings and in illustrating technical books and catalogues. Isometrics are also especially useful in illustrating shop processes and methods, and certain manufacturing firms operating under the so-called "scientific management" use this method of giving very definite and minute instructions to the workmen, as, for examples, the best method of fastening a certain piece of work in a machine, the proper way to take cuts from the piece, etc. Some of the large steel manufacturers are using isometric drawings practically to the exclusion of mechanical drawings.

**Some of the advantages of isometric drawings are:** (*a*) they can be easily made and understood; (*b*) they give, in a single view, the information that requires two or more views if a mechanical drawing is made use of; (*c*) practically no ability to " visualize " is necessary in reading isometric drawings, and in this respect they resemble perspective drawings but possess an

advantage over perspective drawings in that they can, in a limited way, be measured and dimensioned similarly to mechanical drawings.

**Some of the disadvantages of isometric drawings are:** (*a*) they show an object " distorted " and often make it appear *unreal;* (*b*) they can be measured (i.e., " scaled ") only in certain directions; (*c*) angles shown in isometric *cannot* be measured in degrees; (*d*) all circles show in isometric as ellipses, and an ellipse is more difficult to draw *with instruments* than a circle, but this is rather an advantage in *free-hand* isometric drawing.

**117. Principles.** Isometric drawing is based on the principles of **isometric projection,** but it is beyond the scope of this text to take up the discussion of the principles underlying this art. For the purpose of this work it will be necessary to state only *two new principles not included in orthographic projection, viz*:

(1) The object to be represented is so placed with reference to the **projection plane** that instead of presenting a single face for projection, *three* faces at right angles to each other and representing the length, width, and thickness of the object will be *equally inclined* to this projection plane and thus all three faces are presented in a single view.

(2) With an object placed as stated in principle (1) above, all vertical lines of the object will be drawn vertical, and all horizontal lines of the object will be drawn at 60 degrees to the vertical or at 30 degrees to a *true* horizontal line.

These principles can be best illustrated by making an isometric drawing of a cube. See § 118, this page.

**118. Isometric Drawing of a Cube.** A mechanical drawing of a cube is shown in Fig. 123 (a) and an isometric drawing of the same size cube is shown in Fig. 123 (b), see page 158.

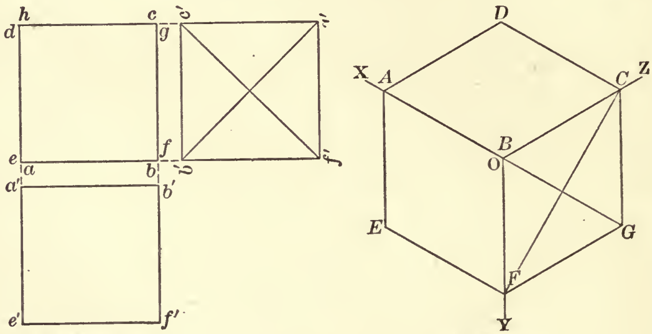
**To construct the isometric drawing,** draw the vertical line O–Y and lay off *B–F* equal in length to the edge *B–F* of the cube; that is, equal to $b'$–$f'$.

From O draw O–X to the left and O–Z to the right, each line making 120 degrees with O–Y; that is, each of these lines will make 30 degrees with a horizontal line.

On O–X lay off a distance equal to the length of the edge *B–A* of the cube; that is, equal to *b′–a′*.

On O–Z lay off a distance equal to the edge *B–C* of the cube; that is, equal to *b′–c′*.

From *A* draw *A–D* equal and parallel to *B–C*. From *C* draw *C–D* equal and parallel to *B–A*. The rhombus* *A–B–C–D* is the *isometric* drawing of the square top *a–b–c–d* of the cube.




(a) Mechanical. (b) Isometric.

Fig. 123.—Drawing of Cube.

From *C* draw *C–G* equal and parallel to *B–F* and from *F* draw *F–G* equal and parallel to *B–C*. The rhombus *F–B–C–G* is the *isometric* drawing of the square face *f′–b′–c′–g′* of the cube.

The face *A–B–F–E* is similarly determined.

119. **Definitions.** The following definitions will be more easily remembered by referring to Fig. 123 (b), this page.

(*a*) The **isometric axes** are three intersecting lines drawn at 120 degrees to one another, one of which lines is vertical, and the other two will be 30 degrees to the *true* horizontal and in opposite directions. The isometric axes are sometimes referred to as the X, Y, and Z axes.

(*b*) The **isometric origin** is the intersection of the isometric axes and it is usually marked O.

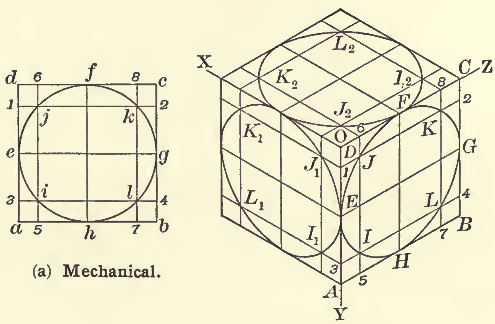
(*c*) **An isometric line** is one which is parallel to *any one* of the three isometric axes.

(*d*) **A non-isometric line** is one which is *not* parallel to any one of the three isometric axes.

* The rhombus (or rhomb) is an oblique parallelogram whose sides are all equal.

(*e*) **Measurements can only be made on isometric lines** and can never be made on non-isometric lines. That is, an **isometric drawing of a solid** can be measured or scaled in only *three* directions and **of a plane figure** in only *two* directions, these directions always being *parallel* to the isometric axes. This principle is illustrated in Fig. 123 (b), page 158. Lines which lie in the face *B–C–G–F* can be scaled, or measured, if parallel to O–Z or O–Y but not if parallel to O–X. This will be understood if diagonals are drawn from *B* to *G* and from *F* to *C*, for though these diagonals are actually equal in length they do not project equally.

**120. Isometric Drawing of a Circle.** The isometric drawing of a circle is *always* an ellipse. To determine points on the ellipse enclose the circle within a square as shown in Fig. 124 (a) and next draw the construction lines *1–2*, *3–4*, *5–6*, etc., so as to intersect on the circle at points *i*, *j*, *k*, *l*. Let it be assumed that the circle lies in a vertical plane. Then the *isometric* drawing of the circumscribed square *a–b–c–d* can be drawn exactly as if it were the face *F-G-C-B* shown in Fig. 123 (b), page 158. The sides of the square *a–d* and *d–c* are made to coincide with the isometric axes O–Y and O–Z, respectively, in Fig. 124 (b), hence *D–6* of Fig. 124 (b) can be measured off equal to *d–6* of Fig. 124 (a) and *D–1* of Fig. 124 (b) can be made equal to *d–1* of Fig. 124 (a). The points *3* and *8* of Fig. 124 (b) are found in a similar manner, and through the points *1*, *6*, etc., the **construction lines** are drawn parallel to *D–C* and *D–A*; these lines, such as *1–2*, and *6–5*, are isometric lines and their intersection *J* is the **isometric position** of *j*, a point on the circle. All other points on the circle, such as *E*, *I*, *H*, etc., are similarly located and the ellipse which is drawn through these points is the *isometric drawing* of the circle. The




(a) Mechanical. (b) Isometric.

Fig. 124.—Drawing of Circle.

ellipse through $I_1$–$J_1$–$K_1$–$L_1$ represents the isometric drawing of the *same* circle when it lies in a vertical plane parallel to the plane of the isometric axes O–Y and O–X. The ellipse through $I_2$–$J_2$–$K_2$–$L_2$ represents the isometric drawing of the circle when it lies in a horizontal plane. The points on these ellipses are found exactly as the points *I–J–K–L* of the first ellipse were found.

**121. Approximate Method of Making an Isometric Drawing of a Circle.** The ellipse when constructed as described in § 120, page 159, represents the *true isometric drawing* of the circle, but an approximate method which is much simpler and at the same time sufficiently accurate for most purposes is shown in Fig. 125. The sides *C–D* and *D–A* are bisected respectively by the lines *B–A* and *E–C*, which are drawn directly from *A* and *C* with the 30–60 degree triangle. With *C* as a center and *C–E* as a radius describe the arc *E–F*. With *A* as a center and with *C–E* as a radius describe the arc *G–B*. With the intersection point *P* of the lines *A–B* and *C–E* as a center and with *P–E* as a radius describe the arc *E–B*. Similarly describe the arc *F–G*. If this work has been *accurately* done the resulting figure will appear as a "smooth" ellipse. The ellipses in the vertical planes can be similarly constructed.

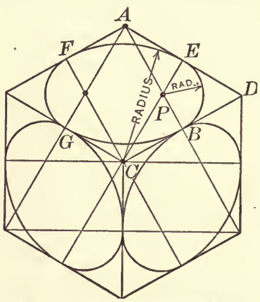
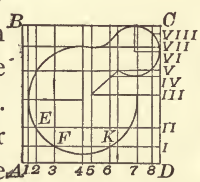
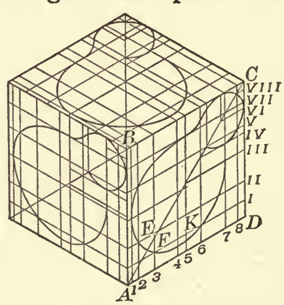



Fig. 125. — Approximate Method of Drawing an Isometric of a Circle.

**122. Isometric Drawing of a Plane Figure Composed of Straight and Curved Lines.** Assume that any plane outline as shown in Fig. 126 (a) is to be represented in isometric. Circumscribe a square or rectangle about the figure to be drawn in isometric as shown in Fig. 126 (a). Through *important*




(a) Mechanical.



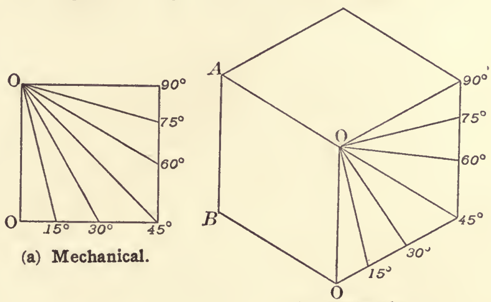

(b) Isometric.

Fig. 126. — Drawing of Any Plane Figure.

points on the figure draw lines parallel to the sides of the circumscribed square. These lines will be *isometric lines of the isometric drawing*, hence *I–K*, *K–6*, *K–F*, *F–3*, etc., of Fig. 126 (b) are drawn respectively equal to *I–K*, *K–6*, *K–F*, *F–3*, etc., of Fig. 126 (a); the *isometric position* of the points such as *E*, *F*, *K* being found by laying off *A–1*, *1–2*, *2–3*, *3–4*, etc., *D–I*, *I–II*, *II–III*, etc., of Fig. 126 (b), equal to the corresponding distances of Fig. 126 (a). Through these points, lines are drawn parallel to the proper sides of the rhombus and the *intersections* of these lines determine the isometric position of the required points.

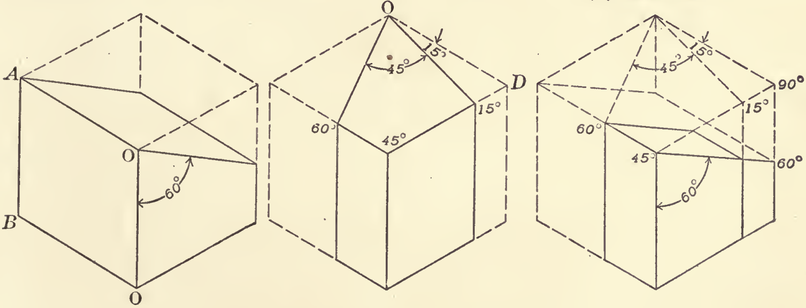
Fig. 126 (b) shows the figure in the horizontal and in the two different vertical *isometric* planes.

**123. Isometric Drawing of a Cube Cut by a Plane.** Assume the cube cut by a plane through its edge and at any angle. First draw one face of the cube in *orthographic* projection, and draw the lines O–*15*, O–*30*, O–*45*, etc., from the corner O and making 15 degrees, 30 degrees, etc., respectively, with the line O–O, see Fig. 127 (a). In Fig. 127 (b) is shown the isometric drawing of this face of the cube with the lines O–*15*, O–*30*, etc., represented as making 15 degrees, 30 degrees, etc., with O–O. In this figure the included corresponding angles are *not* equal to those of



(a) Mechanical.

(b) Isometric.



(c) (d) (e)

Fig. 127.—Cube cut by Planes.

Fig. 127 (a), but the distances O–*15*, O–*30*, etc., measured on the bottom line of Fig. 127 (b) are equal to the corresponding distances of Fig. 127 (a).

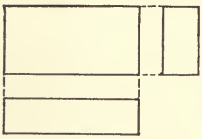
In Fig. 127 (c) a cube is shown in isometric as it would appear if cut by a plane through the edge O–*A*, and at 60 degrees to O–O.

In Fig. 127 (d) a cube is shown in isometric as if cut by two planes, one at 15°, the other at 60° with the back top edge O–*D*.

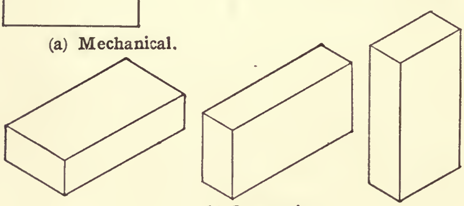
In Fig. 127 (e) a cube is shown in isometric as it would appear if cut, first, as in Fig. 127 (c), and then as in 127 (d).

**124. Isometric Drawing of Wall.** Fig. 128 (a) shows a mechanical (or orthographic) drawing of a rectangular object, and Fig. 128 (b) shows isometric drawings of the block in three different positions. Fig. 128 (c) shows an ordinary isometric drawing which represents a wall built of blocks as shown in Fig. 128 (b).

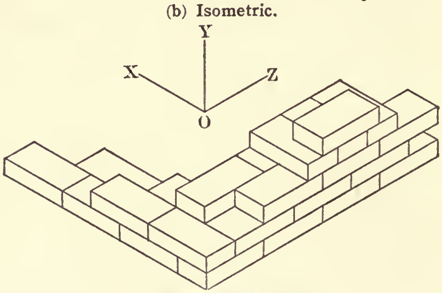
Fig. 128 (d) shows a different view of a wall similar to that of Fig. 128 (c) but having the horizontal lines in a *downward* direction instead of upward as in previous work. Drawing the horizontal downward is called *reversing* the axes, and this method can be used to show the *lower face* of an object, representing it as if tilted *backward* instead of forward, the method of construction, however, being the same in either case.



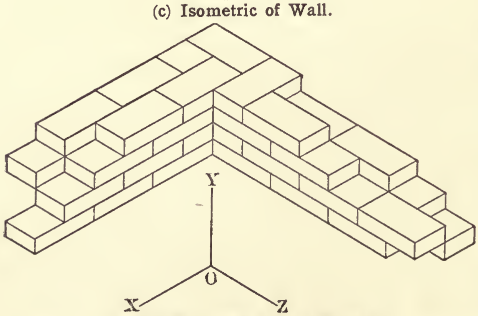
(a) Mechanical.



(b) Isometric.




(c) Isometric of Wall.




(d) Isometric with Axes Reversed.

Fig. 128. —Isometric Drawings of Wall Built of Blocks.

**125. Isometric of a Cylinder.** Make a drawing of a cube that will just enclose the cylinder, then draw the ellipse within the rhombus that represents the top of the cube. See Fig. 129. Likewise construct the base of the cube, and connect the top and the base with tangent lines as shown in the figure.

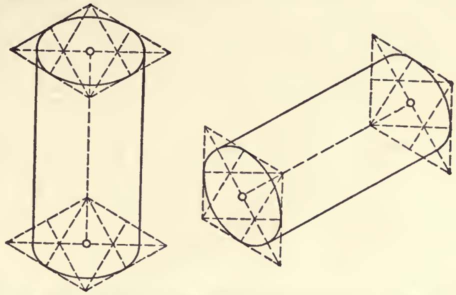


**Fig. 129.—Isometric Drawings of Cylinder in Different Positions.**

**126. Isometric of Screw Threads.** In order to save time the true forms of screw threads are *never* shown in isometric drawings. The **conventional method** of representing the threads is

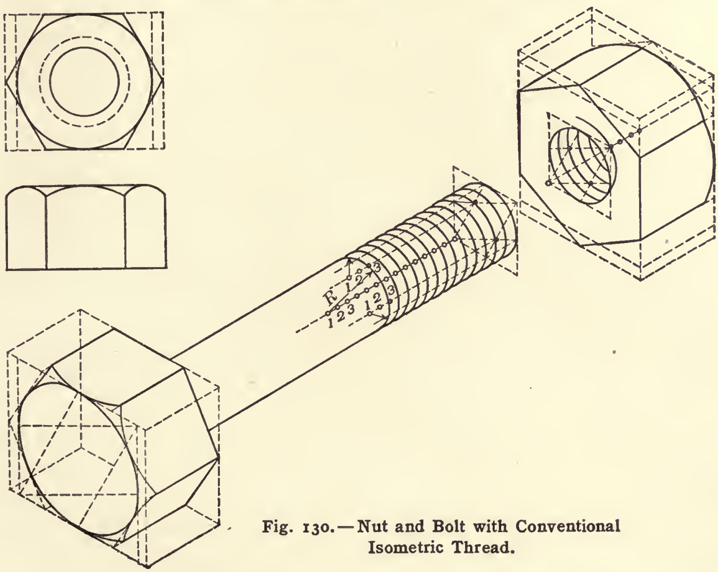



**Fig. 130.—Nut and Bolt with Conventional Isometric Thread.**

shown in Fig. 130. To make such a drawing consider the body of the bolt as a cylinder and proceed as in § 125, this page. The ellipse which represents the base of the cylinder *is to be repeated* in the proper positions to indicate the threads, the distances between the ellipses usually being taken equal to the pitch of the thread; that is, the distance between the ellipse centers is equal to the thread pitch. See "centers" at *1*, *2*, *3*, etc., in Fig. 130.

The internal thread shown in the Nut is similarly constructed.

**127. Hollow Cylinder with a Quarter Section Removed.** It is very often advisable to show an object with a section removed as in Fig. 131.

This drawing is of a Lathe Spindle (see Frontispiece, also Fig. 147, page 172). To construct such a drawing proceed as in

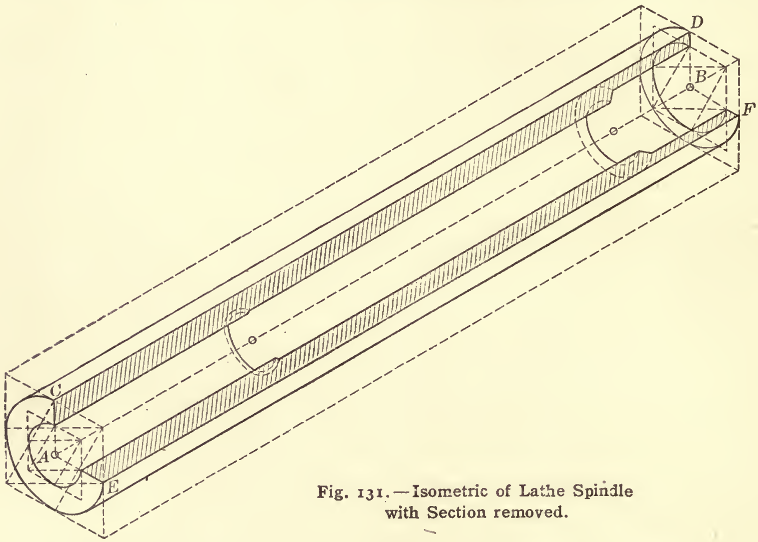



Fig. 131.—Isometric of Lathe Spindle with Section removed.

§ 125, page 163, to obtain the outline of the cylinder. Next, consider the hole in the cylinder as a second cylinder and draw in its outline. To "take out" the section a plane such as *A–B–D–C* is assumed passed vertically through the axis *A–B* of the spindle and a plane, such as *A–E–F–B*, is assumed passed horizontally through the axis. In this construction note that the centers of all ellipses are on the axis *A–B* and their respective distances from the ends of the spindle are measured *on this axis.*

**128. Offset Construction in Isometric Drawing.** It is not always necessary to enclose the object completely in a cube or rectangle, as described in § 122, page 160, in order to make an isometric drawing. See also § 125, page 163. It frequently occurs that the *isometric lines* can be drawn more readily by the **offset construction** as illustrated in Fig. 132, page 165.

**129. Isometric Drawing of a Sphere.** The isometric drawing of a sphere is *represented by a circle.* To determine the radius of this circle, make an isometric drawing of a circle having the *same*

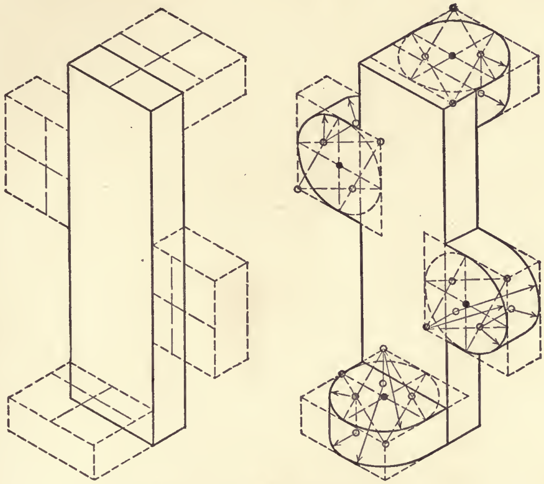


Fig. 132.—Offset Construction.

diameter as the sphere. The radius of the circle which represents the sphere will be equal to *one-half* the major axis of the ellipse which represents the circle. In Fig. 133 is shown a sphere of diameter $D$. The *dashed* ellipse shown in Fig. 133 (b) is the

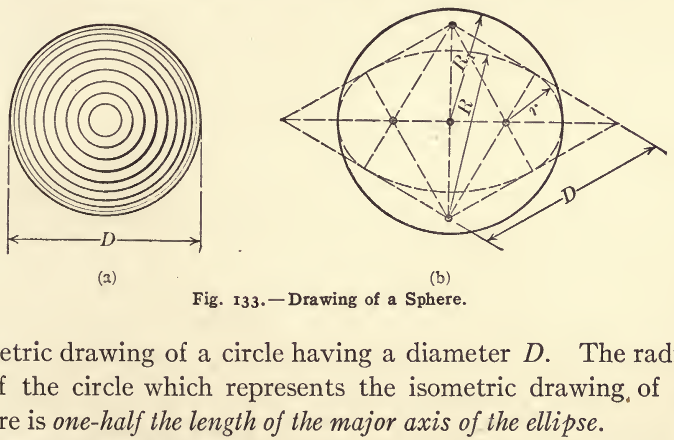
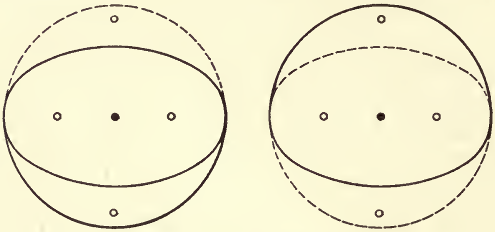



Fig. 133.—Drawing of a Sphere.

isometric drawing of a circle having a diameter $D$. The radius, $R$, of the circle which represents the isometric drawing of the sphere is *one-half the length of the major axis of the ellipse.*

**To draw a half-sphere** construct the outline of the sphere as described above. Next draw the ellipse which represents a *great*

*circle* of the sphere. In Fig. 134 (a) is shown the lower half of a sphere and in Fig. 134 (b) is shown the upper half.



(a) Lower half. (b) Upper half.
Fig. 134.—Isometric of a Half Sphere.

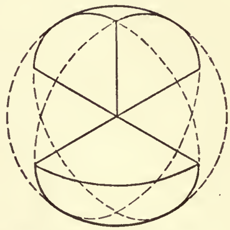


Fig. 135.—Isometric of One-eighth Sphere.

**To draw one-eighth of a Sphere** construct the sphere as described above and next draw the *great circles* at right angles to one another as shown in Fig. 135.

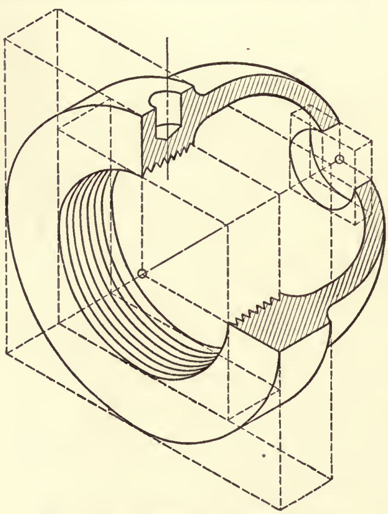


Fig. 136.—Isometric of Lathe Cap.

**130. Isometric Drawing of Lathe Cap.** To get an idea of the exact shape of the **Lathe Cap** see Frontispiece and Fig. 148, page 172. The Cap is a combination of a cylinder (see § 125, page 163), a half sphere (see § 129, page 165) and of V threads (see § 126, page 163).

Fig. 136 shows an isometric drawing of the Lathe Cap with one-quarter section removed.

**131. Size and Numbering of Sketch Sheets.** Exercises in isometric sketching are to be done on small sheets of standard letter size (8″ × 10½″) heavy weight isometric-ruled paper (see § 4, page 5), the ruling on one side only. The paper is to be punched for standard No. 10 Manila cover. As previously stated, one of the disadvantages of making isometric drawings *mechanically* is due to the frequent necessity of drawing ellipses. This, however, is an advantage in *free-hand* sketching, since the ellipse is more easily drawn free-hand than the circle. The chief

objection to making isometric sketches is due to the difficulty of maintaining the thirty-degree angle. This difficulty can be entirely overcome by the use of isometric ruled paper, see Fig. 1 (b), page 5. This paper has, besides the regular vertical and horizontal ruling of the ordinary cross-section paper, also lines ruled at thirty degrees to the horizontal. This ruling insures the proper slope to all isometrically horizontal lines and *the draftsman needs no other instruments than a pencil and measuring rule to make isometric drawings of the most complex nature.*

The order in which free hand isometric sketch sheets are executed will be indicated by *Roman* numbers beginning with I and continuing as far as necessary. For the general system to be followed see Appendix A, page 175.

## SET OF FREE-HAND ISOMETRIC EXERCISES.

**132. Sheet I.** The purpose of this sheet is to give practice in making an Isometric Drawing of a simple object and also to bring out some of the elementary principles of Isometric Sketching.

Before starting to draw, read, and be prepared for examination on, paragraphs, as follows:

Ruled Paper, page 5, § 4. — Lead Pencil, page 14, § 14. — Erasers and Erasures, page 16, § 15. — The Free-hand Pencil Line, page 134, § 95. — Introductory, page 156, § 116. — Principles, page 157, § 117. — Isometric Drawing of a Cube, page 157, § 118. — Definitions, page 158, § 119. — Isometric Drawing of a Circle, page 159, § 120. — Size and Numbering of Sketch Sheets, page 166, § 131, and for information on the general system to be followed see page 175, Appendix A.

*Exercise on Sheet I.* This exercise consists of an Isometric sketch of Tool Rest Support Slide for the Lathe, see Fig. 137; also Frontispiece.

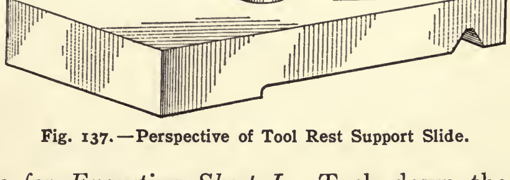


Fig. 137. — Perspective of Tool Rest Support Slide.

*Specific Instructions for Executing Sheet I.* Tack down the isometric ruled sheet, stamp in the title-form (see Fig. 93, page 138) in the lower right-hand corner of sheet, and neatly write *with ink* the wording of the title.

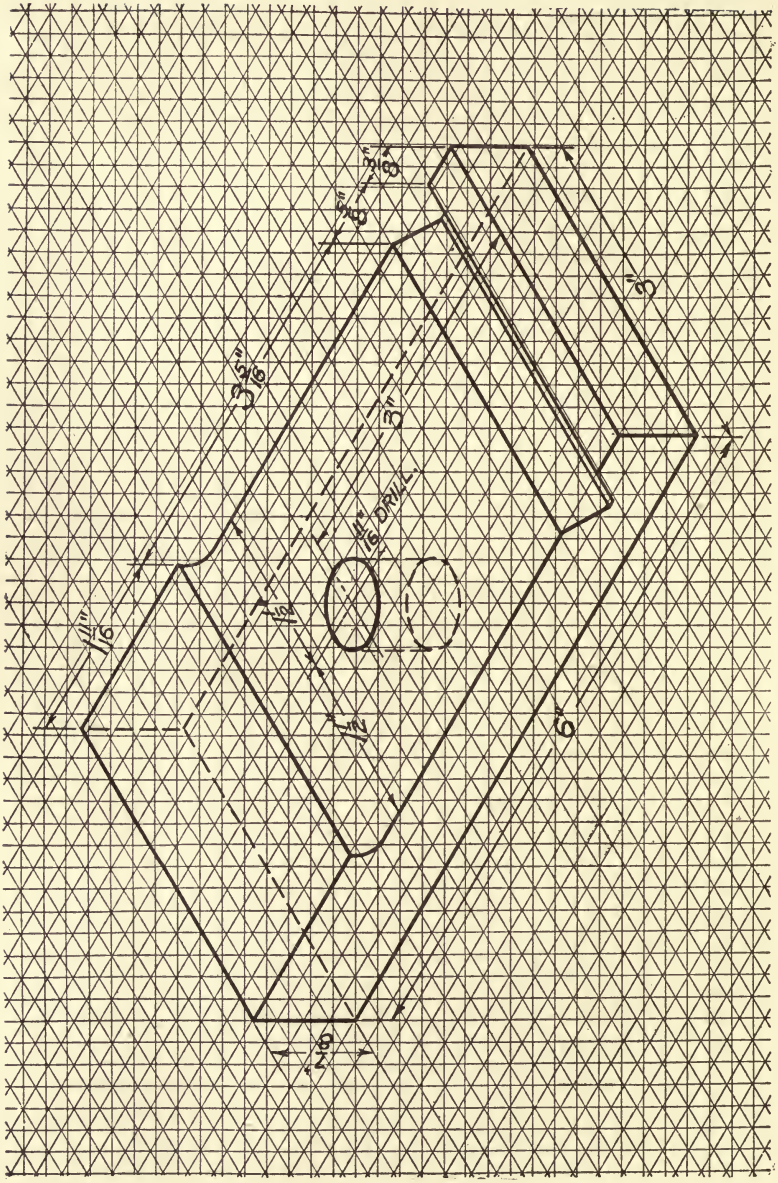



Fig. 138.—Model for Sheet I.

The title of sheet I is Support Slide.

Do not use a straight-edge in any of this free-hand course as this will seriously impair the value of the work.

Make a pencil perspective sketch of the Support Slide on central portion of the sheet, and to about the scale shown in Fig. 138. Dimension the sketch, and when the sheet has been cleaned and all the lines made clear cut and of the desired weight and construction, and the work is thoroughly checked, submit it for inspection and approval. Compare this sketch with Fig. 51 (b), page 74, and determine in your own mind which conveys the necessary information with the fewer lines, also which would be the more readily understood by the average person who would use drawings.

**133. Sheet II.** The purpose of these exercises is to give further practice in making Isometric Sketches of simple objects.

Before starting this exercise, read and be prepared for examination on, paragraphs, as follows:

Approximate Method of making an Isometric Drawing of a Circle, page 160, § 121. — Isometric Drawing of a Plane Figure composed of Straight and Curved Lines, page 160, § 122. — Isometric of a Cylinder, page 163, § 125. — Isometric of a Screw Thread, page 163, § 126.

*Exercises on Sheet II.* The exercises on this sheet consist of pencil Isometric Sketches of a Key (see Fig. 139), of a Shim (see

**Fig. 139. — Perspective of Key.**

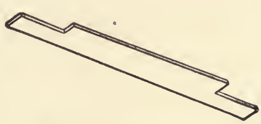


**Fig. 140. — Perspective of Shim.**

**Fig. 141. — Perspective of Stud.**

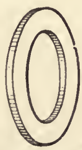


**Fig. 142. — Perspective of Fiber or Steel Washer.**

**Fig. 143. — Perspective of Special Nut.**

Fig. 140), of a Stud (see Fig. 141), of a Washer (see Fig. 142), and of a Nut (see Fig. 143), all of these being parts of the Speed Lathe as shown on Frontispiece.

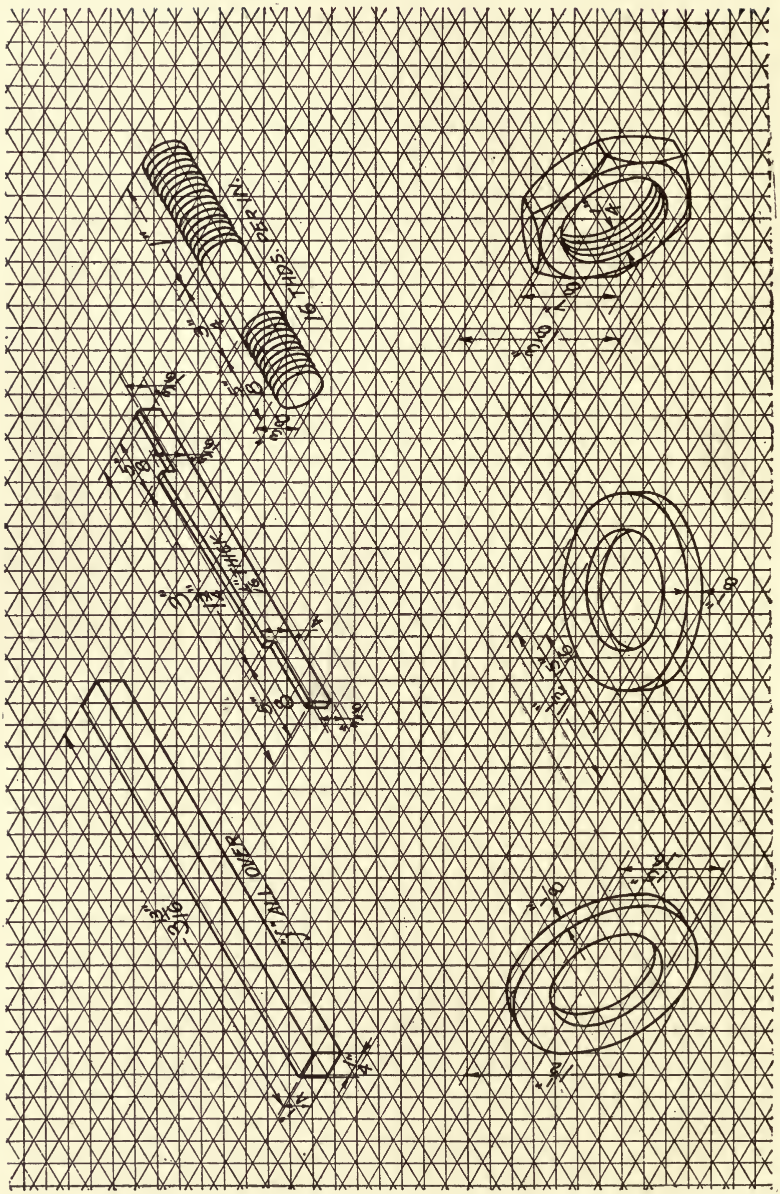



Fig. 144.—Model for Sheet II.

*Specific Instructions.* Stamp the title-form (see Fig. 93, page 138) in lower right-hand corner of sheet and write *in ink* the wording of the title.

The title of this sheet is Speed Lathe Details.

Sketch in these parts similar to the way they are shown in Fig. 144, dimensioning the figures.

Having perfected the sketches, submit for approval.

Compare the sketches on this sheet with similar parts shown in Fig. 82, page 118, and Fig. 97, page 140, and in your own mind determine which is the best and quickest method of representing these objects.

**134. Sheet III.** The purpose of the exercises on this sheet is to give practice in making Isometric Sketches directly from the object and in dimensioning these sketches, the dimensions being obtained by direct measurement of the object.

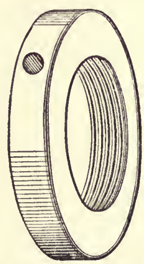


**Fig. 145. — Perspective of Collar.**

*Exercises and Specific Instructions.* The exercises on this sheet consist of Isometric Sketches of a Collar (see Fig. 145) and of a Bearing (see Fig. 146) made from direct observation of these parts, and all dimensions and notes necessary are to be put in, the dimensions being obtained by measurements made directly on the Collar and the Bearing.

Stamp in and fill out the title form.

The title of this sheet is Speed Lathe Details.

Check the drawing thoroughly and submit for approval.

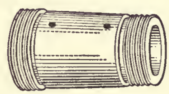


**Fig. 146. — Perspective of Bearing.**

**135. Sheet IV.** The purpose of this exercise is to give practice in making an isometric sketch in ink and in showing an object with a quarter section removed, the sketch being on plain paper.

Before starting to draw, read and be prepared for examination on paragraphs as follows:

Freehand Inked Line, page 136, § 96. — Isometric Drawing of a Cube cut by a Plane, page 161, § 123. — Hollow Cylinder with a Quarter Section Removed, page 164, § 127.

*Exercise and Specific Instructions.* Tack down a standard size sheet of *plain paper* of good quality to take ink and make an Isometric Sketch, in pencil first, of Lathe Spindle (see Fig. 147)

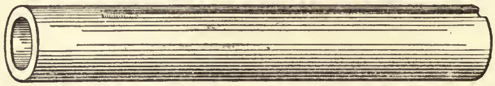


Fig. 147.—Perspective of Tailstock Spindle.

similar to Fig. 131, page 164, except the keyway is to be shown and the sketch dimensioned from the object. The sketch having been perfected in pencil, it is to be neatly inked in.

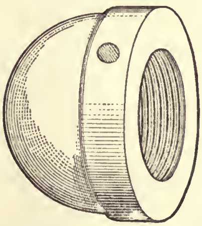


Fig. 148.—Perspective of Lathe Cap.

The title of this sheet is Lathe Spindle.

**136. Sheet V.** Make an isometric drawing of a Lathe Cap (see Fig. 148), with a quarter section removed (see Fig. 136, page 166).

Before starting to draw, read and be prepared for examination on paragraphs as follows:

Isometric Drawing of a Sphere, page 165, § 129.—Isometric Drawing of a Lathe Cap, page 166, § 130.

*Specific Instructions.* Stamp in and fill out the title form.

The title of this sheet is Lathe Cap.

Make all lines very light until the correct outline is obtained; clean the sheet and sketch in the object clear cut and complete.

Submit the sheet for approval.

**137. Sheet VI.** An isometric sketch is to be made of a Lathe Shelf Bracket (see Fig. 149), showing the object in two different positions, as illustrated in Fig. 150, page 173. This sketch is to be finished up in pencil and then inked in freehand.

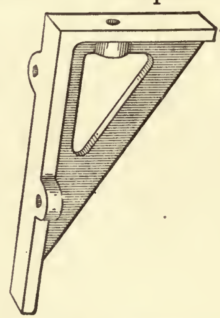


Fig. 149.—Perspective of Shelf Bracket.

Before starting this drawing, read, and be prepared for examination on, paragraphs, as follows:

Isometric Drawing of a Wall, page 162, § 124.—Offset construction in Isometric Drawing, page 164, § 128.

The title of this sheet is Shelf Bracket.

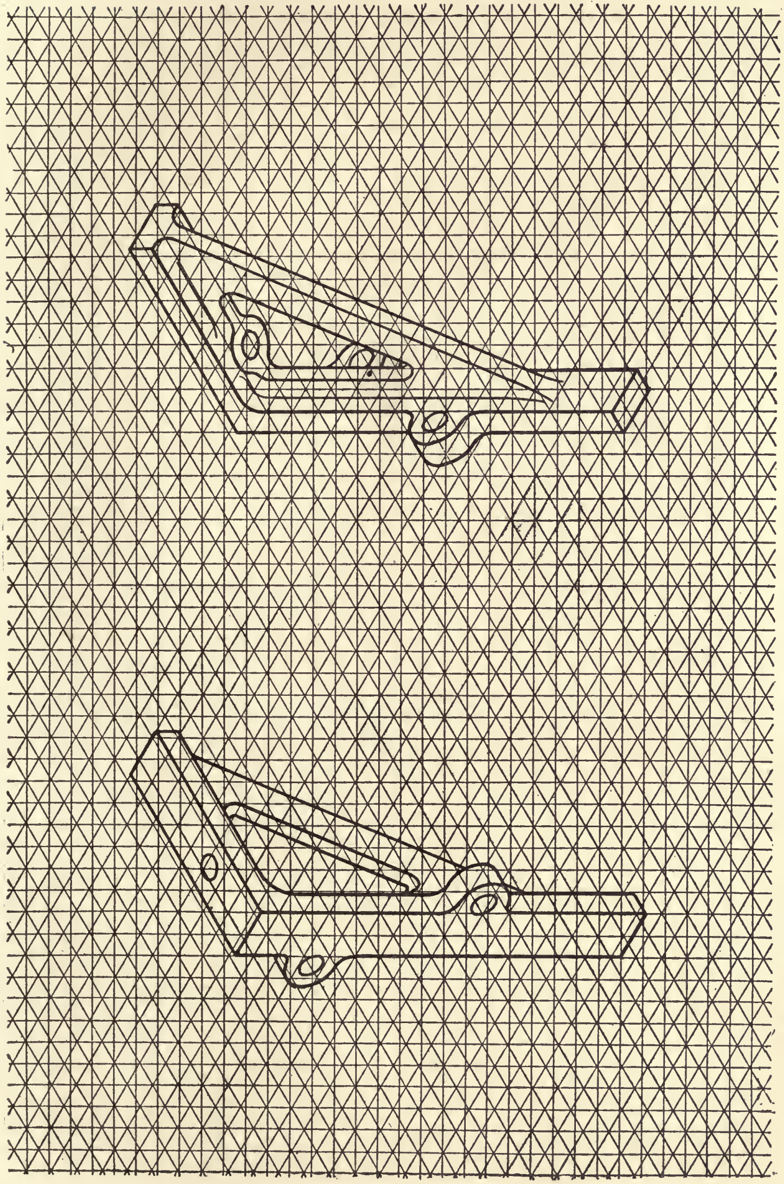


**Fig. 150.—Model for Sheet VI.**

**138. Examination on Chapter V.** As a final examination on this chapter make an Isometric Drawing of Tool Rest Support (see Fig. 151) or of any other parts of the Lathe or of parts of any other machine assigned, on plain or ruled paper, and in pencil or ink as directed. Also study the subject matter contained in § 116, page 156, to § 132, page 167, in preparation for examination.

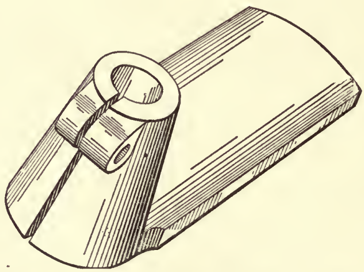


Fig. 151.—Perspective of Tool Rest Support.

# APPENDIX A.

## DRAWING ROOM SYSTEM.

**139. Commercial Drawing Rooms.** In practically all commercial drawing rooms work is carried on under some fixed system, the nature of which depends upon the character and scope of the work to be accomplished. Such systems usually require that drawings be made to certain standard sizes; that a certain title form providing for specific information be used; that certain styles of lettering be used; that certain conventions and abbreviations be used, and so forth. The value of doing the work of this course under an efficient system can therefore be readily understood, and it is expected that either the system as outlined below or a system provided by the instructor will be followed.

(*a*) **General Method of Procedure.** Having secured *instruments* and *supplies* (see § 2, page 2) proceed with the drawing course beginning with the set of Freehand Lettering Exercises as outlined in § 38, page 44 to § 52. Next take up the set of Mechanical Drawing Exercises as outlined in § 79, page 116, to § 91. Then take up the set of Freehand Drawing Exercises as outlined in § 100, page 139, to §116, and finally take up the set of Isometric Freehand Sketching Exercises as outlined in § 132, page 167, to § 139.

In working up the exercises on each sheet or drawing proceed in the following manner:

1. Read all text matter assigned and be prepared for examination on same.

2. Tack down the sheet or drawing (see § 73, page 107) and where necessary draw in the border line (see § 72, page 106).

3. Put the title form in the lower right-hand corner. Write in *with ink* the wording of the title form as far as possible.

4. Proceed with the actual drawing as instructed in the text.

NOTE. Satisfactory progress can be made only when the beginner learns to criticise his own work intelligently as it

proceeds and when he forms the habit of making at once any changes found necessary from his own criticism or suggested by the instructor.

*Before requesting the instructor to finally inspect a piece of work, the student must check every exercise and bring the work as a whole up to the highest standard of perfection of which he is capable.*

When the exercises appear satisfactory to the instructor, he signs his name (or initials) in the title form after the word "*INSPECTED.*" The student is then to write with ink the *DATE FINISHED* and the *TOTAL ACTUAL HOURS* expended on the work; it is then deposited in some prescribed place in order that the instructor may further check it if thought best.

If deficiencies are found in checking the work, *it will be returned once* for the student to make the corrections and changes indicated. Exceptional care must be taken, when making changes to avoid spoiling the work.

*Work not neatly and accurately corrected will not be approved.*

All changes and corrections indicated must be made at the earliest possible date and the corrected work immediately returned to the proper place by the student.

*If the quality of work done on any part of the sheet, drawing, tracing, or plate is unsatisfactory and cannot be brought to the required standard of perfection by the student, it must be repeated until all requirements are met.*

When inspected work is not returned to the student within a reasonable length of time, this indicates that the instructor in further checking has found no serious deficiencies and has given the work final approval.

*In no case is a student to trace a drawing, make a drawing from a sketch, or do any advanced work which depends upon work previously done, unless the original has been finally approved by the proper instructor.*

(*b*) **Sizes of Drawings.** All *lettering, sketching and computing work* is to be done on "sheets" measuring 8″ by 10½″. (See page 44, § 37; page 139, § 99; page 166, § 131.) All *mechanical drawing* is to be done on paper or tracing cloth, measuring 12″ by 18″, this size to be designated by a Capital C. (See page 106, § 72.)

(*c*) **Position of Sheet or Drawing on the Board.** All sheets and drawings are to be tacked down with the *short* dimensions to the sides unless other instructions are given. The punched holes of the " sheets " should be at the top and the punched holes of the " drawings " on the left-hand side. (See page 107, § 73.)

(*d*) **Border Lines.** No border line is to be used on small " sheets," but on " drawings " the border line shown in Fig. 73, page 106, is to be used.

(*e*) **Numbering and Lettering of Sheets and Drawings.** Sheets of *Lettering* will be designated by capital letters, beginning with *A*. Sheets of *Freehand Drawing* will be designated by Arabic numbers beginning with *1*. Sheets of *Isometric Freehand Drawing* will be designated by Roman numbers beginning with I. *Mechanical Drawings* will be designated by the word " *DRAWING*," followed by the capital Letter *C*, which is then followed by the number of the drawing — the first drawing being 101, thus *DRAWING C* — 101.

(*f*) **Title Form and its Location.** On small " sheets " of *Lettering*, *Sketching*, and *Computing* the small Title Form as shown in Fig. 93, page 138, is to be used. For *Mechanical Drawings* of the 12″ by 18″ size the large Title Form as shown in Fig. 69, page 100, is to be used. The wording, however, is to be appropriately modified.

On *sheets* the title form is to be located in the lower right-hand corner. On *drawings* with border lines the title form is to be located in the lower right-hand corner just within the border lines, unless other instructions are given.

(*g*) **Bill of Material and its Location.** On *drawings* requiring a bill of material the Bill of Material form shown in Fig. 70, page 101, is to be used and is to be located just above the title form, unless other instructions are given.

(*h*) **Style of Lettering.** The *Freehand Slant Gothic alphabet* is to be used. (See Fig. 42, page 57; Fig. 43, page 61; § 44, page 62; § 45, page 68).

(*i*) **Conventions and Abbreviations** as given in the text matter are to be used whenever necessary, and uniformity in this regard is to be strictly maintained.

# INDEX.

## A.



## B.

E.

F.



G.

## H.



## I.

M.

Q.

R.



S.

W1d+ hc

150 mt